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A LUMP OF CHALK,

Its Family Circle,

AND THEIR USES,

BY

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WITH ILLUSTRATIONS.

"Where is the dust that has not been alive?"—YOUNG.

A. JOHNSTON,

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PREFACE.

THE very favourable reception accorded to "A Lump of Coal," tempted its Author to prepare the present little treatise upon Chalk, and the various substances with which it is indirectly associated in the grand operations of Nature.

To render the work interesting to the general reader, an outline is given of the various useful purposes to which Chalk, and also Lime and its numerous compounds, are applied in the arts, manufactures and agriculture; and it is hoped that the variety and interesting nature of the accumulated facts will prove not only entertaining but instructive.

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THE HISTORY OF A LUMP OF CHALK.

CHAPTER I.

Chalk: What it is Composed of—Origin of Chalk—Carbonate of Lime a widely-diffused Mineral.

BEFORE entering fully into our subject, it may perhaps be as well to say a few words upon the chemistry of chalk, and thus enable the reader more readily to understand its connection with the numerous substances referred to in the following pages. Chalk, then, is *native carbonate of lime*, and is composed of a metal called *calcium*, combined with oxygen and carbonic acid. When chalk is made red-hot for a considerable time, in presence of atmospheric air, its carbonic acid escapes, and *Lime*, or *Quicklime (oxide of calcium)*, remains behind. Calcium is a white brilliant metal; it decomposes water when coming in contact with that fluid, and if a piece of the metal be slightly heated, it burns brilliantly in the air, like magnesium wire, leaving a residue, which is quicklime.

We have said that chalk is carbonate of lime; but, however paradoxical it may appear, carbonate of lime is not always chalk. For example, marble is carbonate of lime, and so also is the crystalline mineral called *calcite*, but these have no

resemblance to chalk, although they possess the same chemical composition.

When chalk is decomposed by an acid, effervescence takes place, owing to its carbonic acid being set free, and its metallic base, calcium, unites with the acid, forming a salt. Thus, hydrochloric acid and chalk form *chloride of calcium*, or muriate of lime, while sulphuric acid and chalk produce sulphate of lime, and so on.

Lime forms the base of a very considerable number of minerals possessing great beauty of structure, and of others which are highly useful in the arts and manufactures, to which we shall hereafter refer.

Carbonate of lime, in its many different forms, is one of the most abundant mineral productions of our globe, forming mountain masses, either crystalline, as calc spar, marble, &c., or compact, as limestone. It occurs in both stratified and unstratified rocks, and as chalk in vast beds in the most recent of the secondary strata. It is also extensively diffused throughout all fertile soils; and, being soluble in water containing carbonic acid, it exists in most springs. Indeed, the hot springs of San Filippo, near Tuscany, are so highly charged with carbonate of lime that the water deposits considerable quantities of this substance, which is taken advantage of in the manufacture of ornamental articles. Carbonate of lime also exists in the bones of animals, the shells of fish, and in the ashes of most plants.

As to the origin of chalk, geologists have held different views. That it is not the result of mechanical *detritus*—that is, rubbed or worn off rocks, like sands and clays—there is no doubt, however. Its existence, therefore, must be accounted for in some other way. Is it a deposit formed by marine *infusoria* existing in a former age? Or the fossilized remains of minute

(microscopic) shell-fish, or is its existence derived from both of these sources? Dr. Buckland says :—" It is a difficult problem to account for the source of the enormous masses of carbonate of lime that compose nearly one-eighth part of the superficial crust of the globe. Some have referred it entirely to the secretions of marine animals, an origin to which we must obviously assign those portions of calcareous strata which are composed of comminuted shells and corallines; but until it can be shown that these animals have power to form lime out of other elements, we must suppose that they derived it from the sea, either directly or through the medium of its plants. In either case, it remains to find the source whence the sea obtained not only those supplies of carbonate of lime for its animal inhabitants, but also the still larger quantities of the same substance that have been precipitated in the form of calcareous strata.

" We cannot suppose it to have resulted, like sands and clays, from the mechanical detritus of rocks of the granitic series, because the quantity of lime these rocks contain bears no proportion to its large amount among the derivative rocks. The only remaining hypothesis seems to be that lime was continually introduced to lakes and seas by water that had percolated rocks through which calcareous earth was disseminated."

In his work on Geology, Dr. Macculloch favours the theory that all limestones owe their origin to organized substances. He says that if we examine the quantity of limestone in the primary strata, it will be found to bear a much smaller proportion to the silicious and argillaceous rocks than in the secondary, which may have some connection with the rarity of testaceous animals in the ancient ocean. He argues that as a consequence of the operations of animals "the quantity of calcareous earth deposited in the form of mud or stone is

always increasing; that as the secondary series far exceeds the primary, in this respect, so a third series may hereafter arise from the depth of the sea, which may exceed the last in the proportion of its calcareous strata."

Sir Charles Lyell,* remarking upon the above observations, says—"If these propositions went no farther than to suggest that every particle of lime that now enters into the crust of the globe may possibly in its turn have been subservient to the purposes of life, by entering into the composition of organized bodies, I should not deem the speculation improbable; but when it is hinted that lime may be an animal product, combined by the powers of vitality from some simple elements, I can discover no sufficient grounds for such an hypothesis, and many facts militate against it.

"If a large pond be made in almost any soil, and filled with rain-water, it may usually become tenanted by testacea,† for carbonate of lime is almost universally diffused in small quantities. But if no calcareous matter be supplied by waters flowing from the surrounding high grounds, or by springs, no *tufa* or shell marl are formed. The thin shells of one generation of molluscs decompose, so that their elements afford nutriment to the succeeding races; and it is only where a stream enters a lake, which may introduce a fresh supply of calcareous matter, or where the lake is fed by springs, that shells accumulate and form marl."

As to marine animals forming deposits of carbonate of lime, we have abundant evidence in all kinds of shell-fish, in corals, madrapores, and many other products of the ocean. That sea-water is supplied with carbonate of lime by springs issuing from calcareous rocks, we know; and it is therefore easy to

imagine that in an earlier period of the world's history the sea was tenanted by myriads of living organisms capable of absorbing this substance from the ocean in its soluble form, and ejecting it in the solid state. If the polypi which form the various species of coral have the power of building up those wonderful structures for their abode from carbonate of lime, obtained from the waters of the ocean, is it not reasonable to believe that the ancient sea abounded in other marine insects and minute testacea to a far greater extent than now, and that to these we are indebted for the chalk of the secondary strata?

Mr. Lonsdale discovered that the chalk of Brighton, Gravesend, and the neighbourhood of Cambridge was crowded with microscopic shells, thousands of which could be extracted from a small lump by scrubbing it with a nail-brush, in water. Among these he recognized vast numbers of the valves of a marine *cypris*, and sixteen species of *foraminifera*. This important discovery tends greatly to support the theory that chalk is in part, at least, the fossilized remains of once living creatures, and the particles surrounding the minute testacea may have been deposited by marine *infusoria* inhabiting the sea in former ages. Probably at this period the waters of the ocean contained a much greater proportion of carbonate of lime than at the present time.

Referring to the presence of carbonate of lime in sea-water, Lyell says, "The lime, therefore, contained so generally in sea-water, and secreted so plentifully by the testacea and corals of the Pacific, may have been derived either from springs rising up in the bed of the ocean, or from rivers fed by calcareous springs, or impregnated with lime derived from disintegrated rocks, both volcanic and hypogene. • If this be admitted, the greater proportion of limestone in the modern formations, as compared with the most ancient, will be explained, for springs in general hold

no argillaceous,* and but a small quantity of silicious matter, in solution; but they are continually subtracting calcareous matter from the inferior rocks. The constant transfer, therefore, of lime from the lower or elder portions of the earth's crust to the surface must cause, at all periods, and throughout an indefinite succession of geological epochs, a preponderance of calcareous matter in newer as contrasted with the older formations."

That the ocean is constantly being supplied with carbonate of lime in solution, by rivers and springs fed by calcareous rocks, is beyond doubt, and were it not so the multitudinous species of shell-fish would soon cease to exist, for their shells are almost wholly composed of carbonate of lime. Again, if there were no testaceous fish in the sea to utilize the calcareous matter, the waters of the ocean would become so strongly impregnated with carbonate of lime that its other inhabitants might not be able to exist in it.

If carbonate of lime, then, is necessary for the development of the shells of fish, so is it also for the shell of the bird's egg; and we know that hens that are ill-supplied with calcareous matter frequently produce what are called "soft" eggs, in which there is a partial, or sometimes even a total absence of hard shell. The egg-shell being dependant upon carbonate of lime for its formation, cannot become developed unless the animal has the proper food which yields this substance. Indeed, as is well known, hens, during the breeding season, will greedily devour large quantities of chalk, mortar, or even egg-shells, to supply their natural requirements.

It is well known, also, that many kinds of plants will not thrive in soils free from, or poorly supplied with, carbonate of lime. Indeed, farmers frequently spread lime over their land

* Of the nature of clay.

when it has become exhausted of this substance by previous crops. Plants which grow in the vicinity of springs impregnated with carbonate of lime secrete a large quantity of calcareous matter.

In volcanic districts, as we have said, hot springs abound, from which water containing a considerable proportion of carbonate of lime is continually flowing, and this, passing over large tracts of land, covers the soil with vast beds of *tufa* or *travertine*. The waters that flow from the Lago di Tartaro, near Rome, and the hot springs of San Filippo, on the borders of Tuscany, are famous examples of calcareous waters.

Water holding a large quantity of carbonate of lime in solution issues from limestone rocks, and as it trickles down through the fissures of the rocks deposits its carbonate of lime, by the gradual evaporation of the water, on the roofs of caverns and hollows, forming elongated conical masses of semi-crystalline matter called *stalactites*, which are often of considerable size. These masses present a remarkably beautiful appearance, and the material is employed by sculptors and the manufacturers of alabaster ornaments. It is known by the name of *calcareous alabaster*, in contradistinction to *gypseous alabaster*, which is a native *sulphate of lime*. The deposit from the hot springs of San Filippo is also much used for making alabaster ornaments and works of art.

CHAPTER II.

The Cretaceous Age—Geological Sketch—Mountain Limestone.

THE Jurassic age, which preceded the Cretaceous or Chalk formation, appears, according to the observations of M. de Beaumont, to have been terminated, at its tenth stage, by a gradual upheaval and depression of the earth's crust in many regions, and these phenomena determine the complete separation of the last stages of the Jurassic or Oolitic period from that which succeeded it—the cretaceous age. Indeed, it is found that the strata which occur immediately above the Oolite, or Jura limestone formation—which was terminated by a violent convulsion of the earth's crust—mark a distinct epoch in the geological history of the globe.

The cretaceous age is divided by M. D'Orbigny into seven stages, or periods, each of which is distinguished by its own special *fauna*,* and the remains of which were deposited in each succeeding stratum of the cretaceous formation. The animals of each stage were perfectly distinct from those of preceding or succeeding periods.

It has been estimated that the mean thickness of the *first cretacean age* is about 8000 feet, or over one mile and a half. The monstrous Iguanodon, the remains of which were discovered by Dr. Mantell, existed in this age. This huge animal derives its name from its resemblance to the Iguana, a land-lizard of inter-tropical countries. The Iguanodon was supposed to be,

* Animals of the period.

when full grown, about thirty feet long, and its body equal in size to that of an elephant. Besides this, tortoises and other reptiles existed at this period, and a remarkable flying reptile, called the *Pterodactyle*, which never appeared on the earth after this epoch. The Purbeck beds, Hastings sand, Weald clay, and the Ashburnham beds are included in this stage of the cretaceous formation. The *second cretaceous* period includes the Specton clay of Yorkshire; the *third stage* the dark-blue marl of Kent, the Folkestone marl or clay and the green sand and chert of Devon. The *fourth stage* includes Merstham fire-stone, and chert of the Isle of Wight. The *fifth stage* includes chalk without flints, and chalk marl, and the upper *plänerkalk* of Saxony. Geologists have concluded, from the fossil woods which they have so frequently discovered, that at this period the land was clothed with beautiful vegetation, but that owing to the violent convulsions which followed, no perfect remains of either plants or terrestrial animals have been discovered. It is also believed that an enormous surface of land must have been submerged in the succeeding period, extending to nearly one-fourth of the entire globe.

The *sixth age* includes the white chalk with flints of the North and South Downs; and from the thickness of the formation (about 1000 feet) it is believed to have been one of the longest periods of the cretacean age. At this period tracts of land in parts of England and France became submerged, while, on the other hand, the sea retired in some places, leaving increased tracts of dry land. At other parts of the globe, also, there was a considerable subsidence of land, and the waters flowed over some parts of Belgium, as far as Maestricht, while the sea extended from France to the south coast of America, and also covering Chili in the western, and Pondicherry in the eastern continent.

It was at this period that fishes of the salmon and perch species were first called into existence, and no less than 1577 new species of animals were created, all of which disappeared at the termination of this period of the cretaceous formation.

The *seventh stage* of the cretaceous period is of less geological interest than those which preceded it, and there are no evidences of its extending to Great Britain. Near the city of Maestricht, however, on the banks of the Meuse, this formation rests upon the white chalk and flints of the sixth cretaceous period, and contains fossils which are quite distinct from those of the Tertiary period which succeeded it. The seventh stage of the cretaceous age was followed by violent terrestrial convulsions, during which the upheaval of submerged land, and the subsidence of other portions of the earth, must have been prodigious. These periodical disturbances occurred during subsequent periods, when huge masses were forced upward forming great mountain ranges of vast extent. Indeed, the Pyrenean mountain chains are found to consist almost entirely of the fossilized remains of minute animals, and it is also remarkable that the pyramids of Egypt were built of a like material.

The above very brief, and necessarily imperfect, sketch of the geology of the cretaceous age, will give some idea of the vast magnitude of this formation, which may have occupied millions of years in its development before the creation of man. At each stage, animals and plants came into existence which were perfectly distinct from those of preceding and succeeding ages. In the cretaceous age, upwards of 5000 species of animals were created which did not exist in the preceding and subsequent ages, and they are, therefore, distinctly characteristic of this age.

We have seen what an important part marine testacea performed in producing- or helping to produce, the vast masses of

chalk which subsequent terrestrial convulsions raised above the waters. So, also, in the Second Tertiary period, did marine *zoophytes* and *foraminifera* abound in the seas. Indeed, so vast were the numbers of *miliole*,* that they formed strata of stone from which nearly the whole of Paris is built. Some idea of the enormous numbers of these minute creatures, which existed so many ages before the creation of man, may be formed when it is stated that a square inch of the stone is calculated to contain at least two-thousand millions of them!

It has been stated that carbonate of lime is one of the most abundant and widely diffused substances in Nature; independent of the great deposits which lie hidden in the depths of the ocean, it forms the principal constituent of many rocks and mountains. Mr. Page observes, "that the mountain, or carboniferous limestone, is one of the most distinct and unmistakable in the whole crust of the earth. Whether consisting of one thick reef-like bed of limestone, or many beds with alternating shales and gritty sandstone, its peculiar corals, encrinites, and shells distinguish it at once from all other series of strata. In fact it forms in the rocky crust a zone so marked and peculiar, that it becomes a guiding-post, not only to the miner, in the carboniferous system, but to the geologist in his researches among the strata.

"The mountain limestone constitutes the principal portion of these rocks in England. They are, however, more widely developed in Ireland, where, in connection with the Devonian group, they cover four-fifths of the island. The great limestone of Alston Moor can be traced to Lunedale in Yorkshire, and from thence to Wensleydale, and at each place the variations in thickness are not great."

* Derived from the Latin word *millium*, or millet seed.

Portlock, in his "Geological Survey of Londonderry," etc., gives the following interesting account of his labours in tracing the course of the limestone formation in some parts of Ireland: "The northern coast of Antrim seems to have been originally a compact body of limestone rock, considerably higher than the present level of the sea, over which, at some later period, extensive bodies of vitrifiable stone have been superinduced, in a state of softness. The original calcareous stratum appears to be very much deranged and interrupted by these incumbent masses; in some places it is depressed greatly below its ancient level; after a short space, one may see it bears down to the water's edge, and can trace it under the surface of the sea; by-and-bye it dips entirely, and seems irretrievably lost under the superior mass; again, however, after a temporary depression, it emerges, and with a similar variation recovers its original height. In this manner, and with repeated viscissitudes of elevation and depression, it pursues a course of fifty miles along this northern coast from the length of Carrickfergus on the east, to Lough Foyle on the west. The southern boundary of the chalky limestone, which is peculiar to this part of Ireland, may be traced at intervals through a space of about seventy miles within the county, from the Whitehead on Carrickfergus Bay, until the circuit is completed, under the precipice called Solomon's porch, at the entrance of Lough Foyle."

He then proceeds to explain how the same formation passes through the neighbourhood of Belfast, in the counties of Down, Tyrone, and Derry, through a circuit of one hundred and twenty miles. "The chalky cliffs may be discovered," he further observes, "a little eastward from Portrush; after a short course, they are suddenly depressed to the water's edge under Dunluce Castle, and soon after lost entirely in, passing near the basalt hill of Dunluce, whose crags, at a little distance from the sea,

are all columnar. At the river Bush the limestone recovers, and shines for a moment along the level of the sea, but immediately vanishes upon approaching toward the great promontory of Benger, which abounds in every part with pillars of basalt. The limestone then becomes invisible for about three miles, after which it reappears, rising to a considerable height in some parts of the coast, with occasional depressions, as far as Ballycastle Bay. "Fairhead," says Portlock, "towering magnificently with massive columns of basalt, again exterminates, and once more rises to the eastward, pursuing its devious course, and forming, on the Elmarne shore, a line of coast the most fantastically beautiful that can be imagined."

CHAPTER III.

Chalk of the Thames Basin—Chalk beds of Kent and Surrey— Rivers of the chalk districts.

THE vast beds of chalk which occur in what is geologically known as the Thames Basin, extend through the counties of Kent, Surrey and Essex, in some parts attaining a width of twelve miles. It would not be possible, in the present little work, to enter very deeply into the geological history of these important chalk districts; since, however, they represent one of the most interesting deposits of the cretaceous age, we will endeavour to give the reader a brief sketch of some of the principal features of this portion of the great chalk formation from the "Report on the Geology of Great Britain."*

* Published by order of the Lords Commissioners of the Treasury.

The River Thames, which is fed by many smaller streams, passes through the chalk escarpment, near Wallingford, and, taking an easterly course, enters the tertiary tract at Windsor, and again touches the chalk from Erith to some distance beyond Gravesend. The following rivers pass through or rise from the chalk in the under-mentioned districts, and become tributaries to the River Thames:—

The *Loudwater* rises from the chalk at West Wycomb, runs wholly in that rock, and joins the Thames at Cookham.

The *Colne* rises from the chalk near North Minnis, has a course of about twenty-six miles, receives the drainage of the tertiary district north of Pinner and Elstree, and flows into the Thames at Staines.

The *Lea* rises from the lowest part of the chalk north-east of Dunstable, flows with a general E.S.E. direction, through Luton and the west of Hertford, and joins the Thames at Blackwall.

The following streams flow into the Thames on the south:—The *Brook* (i.e. the *Pang*) rises in the chalk near Hampstead Norris, and joins the Thames at Pangbourne, partly communicating also with the Kennet, on the north.

The *Kennet* rises in the chalk tract westward of Marlborough (the most westerly part of the London Basin), and, flowing eastward, receives other chalk brooklets, besides the stream from the upper green sand of Shalbourne, and the drainage of part of the tertiary beds between Hungerford and Newbury, enters the tertiary district west of the latter town and joins the Thames at Reading.

The *Loddon* rises in the chalk near Basingstoke, joining the Thames at Twyford.

The *Whitewater* rises in the chalk west of Odiham, and joins the *Blackwater* just above Swallowfield.

The *Wey* rises in the chalk and upper green sand near

Alton, flows through Farnham and Godalming, where it is joined at Tilford by another stream. At Godalming the Wey turns northward, flows over the inlier of weald clay, and passes through the great chalk ridge of Guildford. From thence this river continues its northerly course, with the dip of the beds, receiving the stream on the S.W. of Woking, finally joining the Thames at Weybridge after a flow of thirty-eight miles.

The *Mole* flows through the chalk beds north of Dorking into the Thames at Hampton Court.

The *Hog's Mill Brook* rises from the tertiary beds near this junction with the chalk at Epsom and Ewell, and joins the Thames at Kingston.

The *Wandle* rises from the chalk at Croydon, flows eastward to Carshalton, and thence northward to the Thames at Wandsworth.

The *Darent*, *Darent* or *Derwent*, rises in the lower green sand at Westerham, flows eastward, parallel with the chalk escarpment, passes through the chalk ridge at Otford, flows through chalk at Dartford, and joins the Thames close to the latter town.

The *Cray* rises in the top part of the chalk at Orpington, flows northward through Crayford, thence eastward until it joins the Darent north of Dartford.

The *Stour* has its origin in the springs from the lower green sand, and from chalk along the foot of the North Downs from Lenham nearly to the sea, these streams meeting at Ashford. The river thus formed takes its course at right angles to those of its component parts, flowing N.N.E. through the lower green sand, through chalk at Chartham, and from thence to Canterbury, below which city it continues its course to the Isle of Thanet, where it divides, the main channel running

eastward to the sea, at Pegwell Bay, and separates the Isle of Thanet from the mainland on the south. The *Wantsome Channel* runs north to the sea near the Reculvers, separating the chalk of the Isle of Thanet from the mainland on the west.

The *Little Stour* rises in the lower chalk near Lyminge and Postling (where another chalk spring takes an opposite direction), and flows on to Barham.

The *Dour* is a small chalk stream running from near Ewell to the sea at Dover.

The chalk formation of the London Basin, below the Middle and Lower Eocene beds, consists of

Upper chalk, with flints.

Lower chalk, without flints.

Chalk marl (?) from 70 feet upwards.

The chalk ranges from 550 to 1000 feet deep.

In the neighbourhoods of Marlborough and Hereford there is a great breadth of chalk ; and on the south, from Marlborough to Dover, the chalk has a higher dip, as also it has from Farnham to Guildford. The chalk also forms the narrow ridge of the Hog's Back, from whence the dip lessens ; but the mass becomes wider, until above Reigate to the sea it is over four miles, and beyond Canterbury over ten miles.

The greatest height which chalk has attained in the south of England is at Inkpen Hill, which is 1011 feet above the level of the sea.

In the county of Surrey the chalk runs from east to west, having, between Farnham and Guildford, a very high dip, but only about half a mile in width, and in some parts only a quarter of a mile ; from the latter town, eastward, the dip lessens gradually, and the chalk tract widens from one to three miles, until, turning northwards, and then eastward, its breadth extends to about seven miles. .

Respecting the chalk formation in East Surrey, Mr. Prestwich infers that it is comparatively thin, sometimes not more than 300 feet in thickness. As it is much thicker northwards, and is known to thin away from Luton, southwards, to London, he concludes that the southerly thinning would be continued.

The county of Kent is famous for its chalk beds, which, in the neighbourhoods of Dartford and Gravesend stretch out beyond the Thames into Essex to a width of about twelve miles, and on the south of Canterbury and Sandwich they have an equal width. In the valley of the Medway the chalk marl is about seventy feet thick, above which there is a mass of grey chalk, succeeded by thick-bedded white chalk, which splits up along the lines of bedding and jointing into larger blocks than the grey chalk beneath it.

Chalk marl, which is composed of carbonate of lime, clay and sand in varying proportions, occurs in soft beds, free from flints, at the lower part of the chalk formation, and forms a fertile soil, suitable for the growth of hops, wheat and clover, and is indeed deemed an excellent and lasting soil for many crops.

CHAPTER IV.

Coral—Coral reefs—How formed—Fossil corals—Pearls—Mother of Pearl.

If we now turn from chalk and limestone to other forms of carbonate of lime, we shall find that a vast field of interest lies before us, not alone from its magnitude but from the marvellous variety which it unfolds to our view. If we explore the wonders of the ocean, we find that the busy *zoophytes* (polypi) have built up, and are still constructing, enormous masses of coral, forming

reefs, some of which are many hundred miles in extent. Again, we have corals resembling trees deprived of their leaves; clusters or groups of cells resembling organ pipes, as in the *Tulipora musica*; corals resembling the mushroom in form (mushroom coral); corals taking the form of the brain, and numerous other varieties, all more or less beautiful, and some of which only exist in the fossil state.

Corals are formed, as we have said, by zoophytes (termed *polypi*) minute marine insects furnished with numerous feelers, or arms, which, when extended, present a star-like appearance—hence they are called *Asteroid polypes*. Other species of the polypus, however, produce, or have formed, the many varieties of coral which exist either in the growing or the fossil state.

Coral is a hard calcareous substance, sometimes of a fine red colour (which is most valued), yellow, pinkish or white. It is composed of numerous cells, each of which is the abode of the creature that forms it. From the tree-like form which corals often assume, they were at one time believed to be of vegetable origin, more especially since their thickened base, when attached to the submarine rocks, bears some resemblance to the lower part of the trunk of a tree. Unlike the ordinary tree, however, the stem and branches of coral extend *downward*, towards the bottom of the sea.

There is nothing in the appearance of a Lump of Chalk which suggests any connection, however remote, with the beautiful substance called *coral*. The former is a soft, easily-powdered substance, of a dull unattractive appearance, while the latter (red coral for example), is a hard, compact substance possessing great beauty of structure, and of a rich and brilliant colour. The Mediterranean seas yield the finest specimens of red coral, and upon the coasts of Provence it was at one time fished up in considerable quantities, thereby forming an extensive industry

in Marseilles. Under the title of *French coral*, it had a high reputation in the earlier part of this century, and was much esteemed as ornaments, in the form of necklaces, bracelets, earrings, etc. •Indeed, even at the present period, old trinkets made from this coral are greatly valued by their possessors.

Coral is almost entirely composed of carbonate of lime—its red colour being due to a small quantity of red oxide of iron. When reduced to powder, it was formerly used as an antacid, in medicine, under the name of *prepared coral*, but for this purpose it would have no advantage over pure chalk. Powdered coral has also been used as a dentifrice or tooth powder.

Madrepores, are also calcareous formations produced by the marine polypus, but they are chiefly discovered in the fossil state. Living madrepores, however, are found in the Red Sea, and in the South American and Indian seas. These calcareous incrustations are built up of myriads of small cells closely packed together, forming concrete ramified masses of considerable hardness.



Fig. 1.

Coral reefs, or islands (fig. 1) are masses of solid rock, formed by the numerous species of zoophytes which abound in the ocean in the warmer regions of the earth. The Pacific Ocean, and

the Arabian and Persian Gulfs are extremely productive of coral. It is also very abundant between the coast of Malabar and the Island of Madagascar. There is a reef of coral on the east coast of New Holland nearly 1000 miles long, and which in one portion is unbroken for a distance of 350 miles.

There are groups of coral islands in the Pacific which are computed at from 1100 to 1200 miles in length, and about 300 to 400 miles in width, as the dangerous Archipelago for example. Amongst the most common species of zoophytes engaged in the production of coral banks are the *Astrea*, *Madrepora*, and *Millepora*.

Respecting the rate of growth of coral reefs, in Captain Beechey's expedition to the Pacific, no accurate information could be obtained of any channel having been filled up within a given period, and it appears that several reefs had remained for more than half a century at about the same distance from the surface. It had been supposed, at one time, that channels and harbours had been closed by the rapid increase of the coral limestone, but it was afterwards suggested by Ehrenberg that the filling up of these havens, in places, was caused by coral-sand, and by large quantities of coral-rock ballast being deposited by vessels.

In the Bermuda Islands, the natives direct attention to certain corals now growing in the sea, which, according to their tradition, have existed in the same spot for centuries. Ehrenberg speaks of single corals of a globular form, which are from six to nine feet in diameter, which must, he says, "be of enormous antiquity, probably several thousand years old, so that Pharaoh may have looked upon the same individuals in the Red Sea." This he considers to indicate that the reef on which they grow has increased at a very slow rate; and after collecting and examining upwards of one hundred species, he found that none

of these were covered with parasitic zoophytes, neither was there an instance of a living coral growing upon another living coral. "To this repulsive power," says Lyell, "which they exert whilst living, against all others of their own class, we owe the beautiful symmetry of some large *Mandrinae*, and other species which adorn our museums."

The anchor of a ship, wrecked about fifty years before, was discovered at an island in the North Pacific, in some fathoms of water, and which, while still preserving its original form, was entirely encrusted by coral. Although this indicates a very slow rate of coral growth, Lyell states that under more favourable circumstances, such as higher temperature of the water, freedom from breakers, sand and mud, a more rapid growth of corals may take place. The apparent stationary growth of coral reefs, as noticed by Captain Beechey, may, Lyell observes, be "due to subsidence, the upward growth of the coral having been just sufficient to keep pace with the sinking of the solid foundations which the zoophytes have built." Dr. Allan made some experiments on the coast of Madagascar, which proved the possibility of coral growing to the thickness of three feet in about half a year. While it is clear that corals do not grow with equal rapidity in different localities, when all circumstances are favourable, it appears that their growth is sometimes considerably accelerated.

Pearls are composed of carbonate of lime intermixed with membranous matter, forming, indeed, a combination resembling bladder and chalk. Nature, however, fashions these beautiful and costly gems in her own subtle way; and although we may conjecture how they are produced, and can ascertain by analysis what they are composed of, we cannot *make* them. The *cause* of the formation of pearls has been thus explained:—When any foreign substance enters the shells of any of the *mollusca* (as

oysters and mussels, for example), which are lined with a pearly matter, or *nacre*, the pearly secretion of the fish, instead of being deposited in layers over the inside of its dwelling (the shell), accumulates upon the surface of the objectionable particle (which forms a nucleus for the pearly deposit) in delicate layers, forming, in process of time, a more or less spherical object—the pearl.

The finest pearls are obtained from an oyster inhabiting the Indian Seas, called the *pearl oyster*. The principal fisheries are on the coasts of Ceylon and the Persian Gulf. An inferior kind of pearl is obtained from a fresh-water shell fish at Omagh, County Tyrone, in Ireland, and also from the River Ythan, in Aberdeenshire. Seed pearls, which have no specific value, are frequently found in ordinary, and especially inferior, oysters and mussels.

Mother of pearl is the internal lining of those shells which produce the pearl itself. It is also obtained from many other shells. The brilliant hues of mother o' pearl are due, not to the substance (carbonate of lime) of which it is essentially composed, but to the method by which it is formed by the animal which secretes it, its surface being covered by minute furrows, which give a *chromatic*, or iridescent (rainbow like) appearance to the light which reflects upon it. Sir David Brewster proved that the rainbow tints of mother of pearl could be imparted to fusible metal, or even to beeswax.

CHAPTER V.

Compact Limestone or Marble—Antique and Modern Marbles —Cement-Stone—Calc Spar—Oolite—Coprolites.

ONE of the most useful of our mineral productions is the *hard carbonate of lime*, commonly called *marble*. Except in chemical composition, it bears no resemblance to other lime-

stones, and is indeed a purer form of carbonate of lime than most of them. The three principal varieties of marble are the *saccharoid limestone*, which, when broken, somewhat resembles loaf sugar, as, the Carrara, or modern statuary marble, for example; the *foliated limestone*, which is formed of minute plates, meeting each other in all directions (ancient statuary marble); and *encrinitic limestone*, which is interspersed with fossil shells.

The variations of colour in marbles are very remarkable, ranging, as they do, from a pure white to an intense black. The colouring matter is generally due to oxides of iron, the blue and green tints being sometimes caused by minute particles of *hornblende*, while the black owe their colour to carbon, or, as in *stinkstone*, to sulphur and bitumen.

Marbles have been classified as follows:—1, White and black marbles; 2, variegated marbles, with irregular veins or spots; 3, madreporic marbles, with animal remains forming white or grey spots; 4, shell marbles, in which only a few shells are interspersed in the general calcareous structure; 5, *lumachella* marbles, composed entirely of shells; 6, *cipolin* marbles, containing veins of greenish talc; 7, *Breccia* marbles, etc.

Of the antique marbles, the finest are the *Parian marble*, of a yellowish-white colour, from which the Venus de Medici and the Arundelian tables at Oxford were formed; the *Pentelic marble*, from Mount Penteles, near Athens, from which the Parthenon, the Hippodrome and other Athenian structures were built, and specimens of which may also be seen among the celebrated Elgin marbles in the British Museum; the *Marmo Greco*, or Greek white marble; the *Marmo Statuario* of the Italians, a semitransparent marble resembling the Parian, from which columns and altars in Venice were constructed; the white marble of Carrara, which often contains transparent rock

crystals (called *Carrara diamonds*); and the black antique marble, which is only found in works of sculpture. Besides these, there are numerous other antique marbles, many of which are so rare as to be only met with in works of art, the quarries from which they were obtained having been either exhausted, or their situation lost, probably by terrestrial disturbance.

There are many varieties of modern marbles, some of which are found in England, in the counties of Derbyshire, Devonshire, and Westmoreland. Black marble is found in Derbyshire; black and white in North Devonshire; and in some parts of the same county many variegated marbles are obtained, some of which possess great beauty—some varieties having a dove-coloured ground, with reddish-purple spots; ash-gray, with black veins; a black ground mottled with purplish globules; and many other varieties of coloured markings.

A very fine white marble is found in Scotland, as also an ash-grey of very uniform grain. In one of the Hebrides a marble is obtained of a pale blood-red colour, with dark-green particles of hornblende, besides many other varieties of remarkable beauty.

The marbles of Ireland—especially those of Kilkenny, Galway, and Kerry—are remarkable for their extreme beauty and the fine polish which they are capable of receiving.

In Anglesea a marble is obtained, the colours of which are greenish-black, green, and occasionally purplish, mixed with white, the latter being due to limestone, and the green tints to asbestos and serpentine.

Italy, France, Sicily, Genoa, and Corsica yield very fine marbles, all possessing characteristics more or less distinct from each other. Many of these, especially the famous Italian marbles, exhibit wonderful varieties of colour (excepting the white and the black marbles). Indeed, all the primary colours,

and their unions with each other, seem to be present in the marbles of Italy. Thus we have the Margorre, bluish, veined with brown; the green marble of Florence; the Sienna marble of a yellow colour, with veins of bluish-red; a light-red marble with yellowish-white spots; a dark red marble from which the Amphitheatre at Verona was built: a yellow marble with white spots, and many other varieties equally beautiful and interesting. There are also very fine shell and also madreporic marbles in Italy.

The following method of forming and polishing a circular slab of black marble will give the reader some idea of the treatment which this beautiful substance undergoes in the process of manufacture into articles of ornament or utility:—
“Having chosen a piece of marble about the size required, and free from veins, etc., to which black marble is very subject, the first process is to level one face, and, with a pair of compasses, strike a circle round the outer edge, then with a mallet and pointed chisel work it roughly to a circular form. It is then ready for the lathe, and being fastened with a resinous cement to an iron chuck, it is screwed to the lathe-spindle, and a very slow motion given to it. The only tool used is a bar of fine steel, about thirty inches long, by three quarters of an inch square, drawn to a point, and well tempered. This is forcibly applied to the marble, which it reduces to the proper form by slowly splicing off small pieces.

“After the correct outline is acquired with this tool it is ready for the grinding process, the first thing being to apply a piece of coarse and hard sandstone with water (the lathe now having a rapid motion) until all the tool marks are ground out. A finer piece of sandstone is then used to remove the coarse scratches of the previous one, and so on with a few other and still finer stones, until all the scratches are obliterated. This

prepares it for polishing. A piece of cotton cloth washed quite clean and well rubbed with flour emery is applied to the marble, and polishes it to a certain extent. A similar piece of cloth is then rubbed over with putty powder (white oxide of tin), which gives a very high polish."—*Tomlinson's Cyclopædia*.

When marble is heated to redness, it becomes converted into *quicklime*, in which respect it differs from common limestone only in being a more pure form of carbonate of lime. White marble is readily distinguished from gypseous alabaster (*sulphate* of lime), to which it bears a slight resemblance, by means of acids, which freely act upon and dissolve the former, with effervescence, but do not affect the latter. Again, gypseous alabaster may be easily scratched by the finger-nail, which would produce no effect upon marble.

Cement stones, so called from being used in the preparation of various kinds of hydraulic or water cements, are found on the Kentish coast, in the Isles of Thanet and Sheppy, on the coasts of Yorkshire, etc. They consist chiefly of carbonate of lime, associated with silica, and alumina (clay), and oxide of iron, and often occur in small nodular masses on the sea shore, having been subjected to the action of the waves. They are chiefly obtained from the argillaceous strata which alternate with the limestone beds of the oolite (or roe-stone) formation, and also in the strata of clay above the chalk. They are of a yellowish-grey colour, and sometimes inclose crystals of *calc spar*.

Calc spar, or *Calcareous spar*, is a native crystallized carbonate of lime, very fine specimens of which are found at the Peak, in Derbyshire, whence it is frequently called *Derbyshire spar*.

Oolite is a variety of limestone, occurring in small globules clustered together, sometimes in layers or strata, and also in a compact form, as in the stone from which the houses in Bath are built. The oolitic series comprises all the strata between

the iron sand above and the red marl below, and forms the chief source of the best building stone which the midland and eastern counties of England produce.

The *Upper Oolite* occurs in the Purbeck strata, the oolite strata of Portland, Tisbury, and Aylesbury, and in other districts. The *Middle Oolite* constitutes the oolitic strata associated with coral rag, calcareous sand and grit, and the Oxford clay, between the oolites of this and the *Lower Oolite*, which contains many strata, occasionally traversed by thin beds of argillaceous deposit. This formation includes the forest marble, schistose oolite, great oolite, inferior oolite, calcareo-silicious sand, etc. The whole series of these formations extend to about thirty miles in width in England. Portland stone is a fine compact oolite, and is much used for architectural purposes, but is not considered a durable building stone.

Coprolite, or *Dungstone*, contains a considerable proportion of lime, combined with phosphorus (*phosphate of lime*). According to Dr. Buckland, it is the fossilized or petrified dung of extinct carnivorous reptiles. Coprolites are found in the secondary and tertiary strata, and are much used in the preparation of artificial manures, for which purpose they are first ground in a mill, and afterwards mixed with an equal weight of oil of vitriol (*sulphuric acid*), whereby *superphosphate of lime* is formed and which, used in suitable proportions, forms an excellent fertilizer.

CHAPTER VI.

Crystallized Carbonate of Lime—Dr. Buckland's Observations on Crystallization—Minerals containing Lime or Carbonate of Lime.

WHEN we look upon a lump of chalk—an almost pure form of carbonate of lime—and observe its dull, lustreless and opaque appearance, and its soft friable nature, we may indeed wonder that such a substance could ever assume the form of a bright, translucent crystal. We know that, chemically speaking,

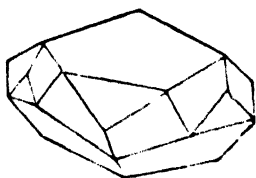


Fig. 2.

charcoal and diamond are the same, that is *carbon*, but how great is the difference in their physical condition ! If we compare a lump of chalk with the beautiful natural crystal calcite (fig. 2), we shall find the contrast equally remarkable.

But our cause for wonder and admiration does not rest here, for Nature, ever varied in her operations, has given us almost endless forms of this widely-diffused mineral. Referring to the beautiful crystalline arrangement which certain bodies assume, Dr. Buckland says, "We may once for all illustrate the combinations of exact and methodical arrangement under which the ordinary crystalline forms of minerals have been produced, by the phenomena of a single species, viz. the well-known substance] carbonate of lime. We have more than five hundred varieties *

* Bournon has described 680 modifications of carbonate of lime, while other authorities state the number to be 750.

of secondary forms, presented by the crystals of this abundant earthy mineral. In each of these we trace a fivefold series of subordinate relations of one system of combinations to another system, under which every individual crystal has been adjusted by laws, acting correlatively, to produce harmonious results.

“ Every crystal of carbonate of lime is made up of millions of particles of the same compound substance, having one invariable primary form—viz., that of a rhomboidal solid, which may be obtained to an indefinite extent by mechanical division. The *integrant molecules* of these rhomboidal solids form the smallest particles to which the limestone can be reduced without chemical decomposition. The first result of chemical analysis divides these integrant molecules of carbonate of lime into two compound substances, namely, quicklime and carbonic acid, each of which is made up of an incalculable number of constituent molecules.” And if chemical analysis be carried further, we find that the lime is a compound of calcium and oxygen, and that carbonic acid is composed of two simple bodies (*or elements*)—carbon and oxygen. Thus we see that two solid bodies—calcium and carbon—each in combination with a gaseous element,* oxygen, combine to form carbonate of lime, whether it be in the unattractive form of chalk, or the more beautiful *Iceland spar*, which is this substance in a primitive form, and of extreme purity.

The following are some of the crystalline minerals which contain lime in the proportions given, but they may be taken as representing only a very small proportion of the numerous minerals of which lime is a constituent :—

Babingtonite contains 19·6 per cent. of carbonate of lime.

* In chemistry an *element* is a simple form of matter which cannot be decomposed or resolved into a simpler form.

It has been found chiefly, if not only, in one of the Shetland isles, associated with white quartz.

Dolomite, or *bitter spar*, is a crystalline mineral (fig. 3), containing from 53 to 56 per cent. of carbonate of lime, and 42 to 44 per cent. of carbonate of magnesia. It is extensively used as a source of magnesia in the preparation of *heavy carbonate of magnesia* for medicinal purposes.

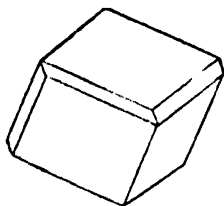


Fig. 3.

Hydrocalcite is also a crystalline mineral, and is found in the basaltic rocks of the Giant's Causeway, in Ireland. It contains, besides water, about 83 per cent. of carbonate of lime.

Aukerite, a crystalline mineral, contains about 51 per cent. of carbonate of lime and 25 per cent. of magnesia, as also iron and manganese.

Alstonite, a crystalline mineral, contains about 30 per cent. of carbonate of lime.

Pennite contains about 64 per cent. of carbonate of lime, and also magnesia, and oxides of nickel and iron.

Plumbo-calcite contains carbonate of lead mixed with carbonate of lime.

Baryto-calcite is a crystalline substance consisting of about 65 per cent. of carbonate of baryta and 33 per cent. of carbonate of lime.

Strontianite contains from 6 to 7 per cent. of carbonate of lime, and when heated by the blowpipe it gives a red flame, which is due to the strontium, an alkaline earth from which nitrate of strontium is prepared for use in pyrotechny.

Fluor spar, or fluoride of calcium is a very beautiful crystalline mineral consisting of about 47 per cent. of *fluorine* and

52 per cent. of *calcium* (the metallic base of lime). It occurs in the form of large cubical crystals, which are frequently of a deep green or purple colour. It is found in Cornwall, Cumberland, Durham, Derbyshire, etc., in England, and also in Ireland, Scotland, and Wales, in Sweden, Bohemia, and other countries. The Derbyshire spar is made into many ornamental articles, which are produced by turning at the lathe. When ground fluor spar and concentrated sulphuric acid are mixed in a leaden retort and distilled, *hydrofluoric acid* is produced; and since this acid has the power of dissolving glass, it is employed for *etching* upon that substance.

Arragonite is a transparent crystalline mineral consisting of pure carbonate of lime. It derives its name from Arragon, in Spain, where it was first found.

Calcite, which is pure carbonate of lime, occurs in crystals of very varied forms, several of which are shown in figs. 4, 5, and 6. Very fine specimens of this mineral have been obtained from many parts of the United Kingdom.

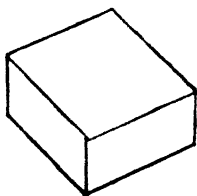


Fig. 5.

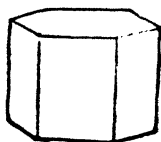


Fig. 6.

Iceland spar is also a pure crystalline carbonate of lime. It has the power of doubly refracting the rays of light.

Idocrase is a crystalline mineral containing nearly 40 per cent. of carbonate of lime.

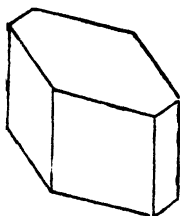


Fig. 7.

Felspar (fig. 7) is the chief constituent of *granite*, in conjunction with mica and quartz. It contains about 1·34 per cent. of carbonate of lime, but its main constituents are silica and potash.

Hornblende.—Under this title are included a great number of minerals which are bi-silicates of metallic oxides, as lime, magnesia, manganese, etc. About 12 per cent. of lime is found in some varieties.

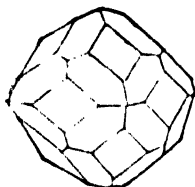


Fig. 8.

Garnet.—This pretty mineral (fig. 8) is composed of silica, alumina, and lime (of which it contains about 34 per cent.), and protoxide of iron. The noble garnet called *almandine*, and the reddish varieties (ruby garnet), are cut as gems. Very fine kinds of garnets are obtained from Pegu.

Beryl, or *aquamarine*, is a beautiful mineral, generally of a delicate green colour, but sometimes of a honey yellow, and sky-blue colour. It closely resembles the emerald in composition, but owes its colour to oxide of iron instead of oxide of chromium, which is the colouring matter of the emerald. Beryl is composed of silica, alumina, glucina, and oxide of iron, with (according to some analyses) from 1 to 2 per cent. of lime. It is stated that enormous beryls have been found in America, one of which weighed 2900 lbs.! The finest beryls are obtained from Brazil and China.

Calc-sinter is the name sometimes given to incrustations of carbonate of lime in the caverns of calcareous rocks. The name is also applied to the stalactites, or conical incrustations of carbonate of lime, found in the caverns of limestone rocks.

Calc-tuff is a name given to the deposit of carbonate of lime from the waters of hot springs and lakes of Tuscany and elsewhere.

Lazulite, a crystalline mineral, contains 3·1 per cent. of carbonate of lime.

Rock salt contains traces of sulphate of lime and chloride of calcium.

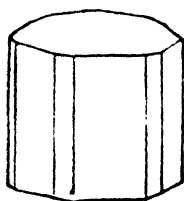


Fig. 9.

Apatite (fig. 9) is a native crystalline phosphate of lime, and contains 41·34 parts of phosphoric acid and 53·38 of lime.

Gyrolite contains 33·24 per cent. of carbonate of lime. It is found in Great Britain, and also in Disco Island, Greenland.

Chabasite, containing 10·47 per cent. of carbonate of lime, is met with in fissures or cavities of basaltic rocks, or associated with quartz and agate, being disseminated in these rocks in Scotland.

Thomsonite contains 13·54 per cent. carbonate of lime. It occurs in the basalt of Aberdeenshire.

Laumonite, containing 9·14 per cent. of carbonate of lime, occurs in massive crystals, in Argyleshire.

Fareölite contains 10·29 per cent. of carbonate of lime. It occurs in the Isle of Skye, Scotland.

Stilbite, containing 7·55 per cent. of carbonate of lime, is found in Cornwall, with *prehnite*.

Diallage contains 17·40 per cent. of carbonate of lime. It is found in Cornwall, associated with serpentine.

Augite contains 24·74 per cent. of carbonate of lime. Found in Durham, etc.

Scolezite contains 14·20 per cent. of carbonate of lime. Found at Staffa, Argyleshire, in trap rock and basalt, in delicate fibrous white tufts.

Datholite, containing 35·40 per cent. of carbonate of lime, occurs in Dumbarton, in small distinct crystals, in basaltic greenstone.

Prehnite contains 26·43 per cent. of carbonate of lime. Found in Cornwall.

Apophyllite, containing 35·20 per cent. of carbonate of lime, occurs in Argyleshire.

Pectolite, containing 35·20 per cent. of carbonate of lime, occurs in the trap and greenstone rocks in some parts of Scotland.

Labradorite, containing 11·00 per cent. of carbonate of lime, occurs in the greenstone, in small crystals, in Stirlingshire, Scotland.

Isopyre contains 15·43 per cent. of carbonate of lime, and is found in the granite near St. Just, Cornwall, associated with tourmaline and tinstone.

Allanite, containing 11·25 per cent. of carbonate of lime, has been discovered by Dr. Beddle in very small crystals in a glen near Criffel, East Kircudbrightshire, Scotland.

Wollastonite contains 44·45 per cent. of carbonate of lime.

Dorante contains 6·00 per cent. carbonate of lime. Found in basalt, near Carrickfergus, Ireland.

The foregoing represent but a very small proportion of the numerous minerals which have been found, by chemical analysis, to contain carbonate of lime, in a greater or less degree. They will, however, help to show how widely diffused is this substance, even apart from its more massive prototype, chalk.

CHAPTER VII.

Sulphate of Lime, or Gypsum—Alabaster—Plaster of Paris —Lithographic Limestone.

THE native mineral called *gypsum* is a compound of lime and sulphuric acid, hence it is a sulphate of lime. It occurs in two chemical states, namely, as *Anhydrite* (that is, *anhydrous*, or

without water) and as *Selenite*, in which water forms a part of its constitution. Anhydrite is composed, in 100 parts, of—

Lime	.	.	.	.	41'53
Sulphuric acid	.	.	.	.	58'47
					<hr/>
					100'00

Gypsum is composed of—

Lime	.	.	.	.	32'90
Sulphuric acid	.	.	.	.	46'31
Water	.	.	.	.	20'79
					<hr/>
					100'00

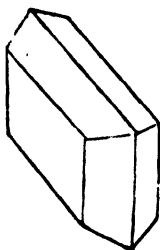


Fig. 10.

Selenite (fig. 10) is the name applied to the more lustrous and transparent varieties of gypsum; the more fibrous varieties are called *satin-spar*; and *alabaster* is the closer and more compact variety of gypsum.

Gypsum is found in various parts of the earth's crust, and in several different geological positions. It is found among the transition rocks, in the red marl formation, and in the tertiary beds, above the chalk. The gypsums found in the Alps belong to the transition series, and are associated with an anthracite coal, some varieties being white, while others are tinted grey, or yellowish, and are sometimes intermixed with mica, talc, compact carbonate of lime, sulphur, common salt, etc.

The gypsum of the salt mine districts occurs in the red marl beds, which lie upon the great deposit of rock salt, while in Cumberland it is found in red argillaceous marl between strata of sandstone. It is found in Derbyshire, Nottingham, and other parts of England, and also in parts of Wales. The gypsums which are found in the neighbourhoods of Paris, as

at Montmartre, for instance, are very famous as forming, when calcined, the well-known *plaster of Paris*. These gypsums contain a large percentage of *carbonate* of lime, to which the great hardening property of the Parisian plaster stone, as compared with pure gypsum, is attributed.

When gypsum is calcined at a low red heat, it loses its combined water and semi-crystalline appearance, and on cooling becomes soft and white. If mixed with water it quickly sets into a hard concrete mass, and on this account is used for taking plaster casts of statues and other works of art.

The close-grained *gypseous alabaster* is much used for carving ornamental vases, statuettes, and other objects, and although this substance is much softer than marble, it is capable of taking a high polish.

Gypsum is much used as a manure for certain soils, being originally employed for this purpose, we believe, by the Americans.

Lithographic stone is a compact slaty limestone, of a yellowish colour, and of exceedingly fine grain. It was formerly chiefly obtained from the quarries of Solenhofen, near Munich, and from the banks of the Danube: but the neighbourhood of Bath now chiefly furnishes the stones used by English lithographers. The limestones used in lithography require to be free from flaws, veins, or other irregularities, and so hard that steel does not readily scratch it. After drawings have been made upon the stone (which is previously rendered smooth by polishing), dilute nitric or muriatic acid is poured over the stone, which, acting upon the carbonate of lime of which it is composed, leaves the design in relief.

Bituminous limestone, which abounds on the Avon, near Bristol, is called *surine-stone*, or *stink-stone*, from the peculiarly offensive odour which it emits on being rubbed.

Lucallite, which also yields the odour of sulphuretted hydrogen on being rubbed, is found in Derbyshire and other parts of England, as also in Cork, Galway, and Kilkenny, in Ireland.

Silicious limestone is a compound of silica and carbonate of lime, and is a very hard and compact stone, possessing great durability.

Magnesian limestone, so called from its being partly composed of the earthy substance, magnesia, forms an extensive series of beds, the geological position of which is immediately above the coal measures.

Magnesian carbonate of lime is oolitic in structure, being composed of small spheroidal masses cemented together either by carbonate of lime, or *chlorite*. Its composition is—

Carbonate of lime	. . .	91.50
„ „ magnesia	. . .	7.04
Water	. . .	0.67

CHAPTER VIII.

Fossil Remains of the Cretaceous Age—The Iguanodon and Hylæosaurus—The Plesiosaurus—The Mosasaurus—The Ichthyosaurus—Fossil Sponges—Ammonites—Fossil Plants.

THE discovery of fossil remains of animals and plants in the various strata of the earth's crust, has enabled geologists and palæontologists to determine the various stages of each geological epoch, by a system of reasoning, based upon known facts, which is not only intelligible to the ordinary understanding, but is accepted by the learned as the most reliable foundation upon

which to build a theory on the formation of the solid portions of the globe.

It would not be possible, in our limited space, to enter deeply into geological considerations; but as a necessary part of the history of our Lump of Chalk, we may call attention to some of the more remarkable extinct species of animals and plants which have, from time to time, been discovered in chalk and limestone, and their congeners, clay, marl, lias, etc.

To the indefatigable researches of Buckland, Lyell, Mantell, D'Orbigny, Professor Owen, and a host of other gifted observers, we are indebted for the vast store of geological and palæontological knowledge which, during the present century, has been so lavishly imparted to us. Aided by the science of chemistry, whose laws had been defined by such philosophers as Davy, Cavendish, Dalton, Faraday, and the great host of English and foreign scientists, the chemical composition of the earth, its waters and surrounding atmosphere have been determined; and our more modern philosophers are now engaged, with their spectroscopes, in endeavouring to ascertain the composition of the heavenly bodies, nor does the wandering comet fail to undergo an examination when night is favoured by a cloudless sky.

Although there were upwards of five thousand species of animals existing in the cretaceous age, the only terrestrial mammalia* discovered in the *secondary strata*, of which the cretaceous formation is the upper portion, are the marsupial quadrupeds, allied to the kangaroo and opossum, which occur in the oolite formation at Stonesfield, near Oxford. Of *reptiles*, however, there were some of very remarkable character, and of enormous size, two of the most interesting being the *Iguanodon* and *Hylæosaurus*, or Wealden lizard, discovered by Dr. Mantell

Animals which suckle their young.

imbedded in Kentish rag, in Tilgate Forest, Sussex, and which are to be seen in the British Museum. These reptiles were herbivorous, their food consisting of the leaves of ferns, conifers (species of *pinæ*), and *cycadæ*, plants somewhat resembling the palm tree, but supposed to be more closely allied to the *conifera*, or fir tribe. Tortoises and other reptiles, including a remarkable species of flying reptile called the *pterodactyle*, existed in the earliest period of the cretaceous age, but the latter never reappeared afterwards.

The remains of the *ichthyosaurus*, or fish lizard, so called on account of their presenting the external appearance of certain orders of fishes, combined with the internal organization belonging to the Saurian (lizard, crocodile) reptiles, were found in the lias of Lyme Regis. Other specimens have also been found at Balderton, in the county of Nottingham, in Whitby, etc.

The *plesiosaurus*, another species of sea lizard, was also found at Lyme Regis, and in the lias quarries of Street, very fine specimens of which are in the fossil collection of the British Museum, where also may be seen the lower jaw, and other parts of the head, vertebræ, etc. of the *mosasaurus*,* a huge land reptile found at St. Peter's Mountain, near the city of Maestricht, Belgium, where the final stage of the cretaceous formation is fully developed, and of which there is no trace in the British strata.

A few genera of birds and fishes existed in the cretaceous age, but the great bulk of animal life seems to have consisted of testaceous marine animals, as cephalopods, gastropods, lamelli-branchia, brachiopods and bryozoa, among the *mollusca*, and

* Dr. Mantell discovered the fossil remains of this animal in the upper chalk, near Lewes, and Dr. Morton discovered the remains of the same extinct animal in the green sand of Virginia.

echinodermata, polyparia, foraminifera, and amorphozoa among the *radiata*. Besides the numerous species of the above orders, the *porifera* or sponges were exceedingly numerous.

"Fossil sponges," Professor Owen observes,* "take an important place among the organic remains of the former world, not only on account of their great variety of form and structure, but still more because of the extraordinary abundance of individuals in certain strata. In England they specially characterize the chalk formation; extensive beds of silicified sponges occur in the upper green sand, and in some beds of the oolite and carboniferous limestone."

The same gifted naturalist says, "The calcareous sponges abound in the oolitic and cretaceous strata, attaining their maximum of development in the chalk; they are now almost extinct, or are represented by other families with calcareous spicula. The *horny*† sponges appear to be more abundant than in the ancient seas, but their remains are only recognizable in those instances where they were charged with silicious spicula.

"The sponges of the chalk belong to several distinct families. Chounitis resembles the siphonia, but is sessile, and exhibits, in section, or in weathered specimens, a spiral tube winding round the central cavity. It is the commonest sponge in the Brighton broach-pebbles. Others are irregularly cup-shaped, and calcareous, and many of the Wiltshire flints have a nucleus of branching sponge (*Spongia clavellata*). The chalk flints, arranged in regular layers, or built up in columns of *paranoudra*, all contain traces of sponge structure, and their origin is in some measure connected with the periodic growth of large crops of sponges. Frequently the crust or outer surface only of the sponges has been silicified, while the centre has decayed,

* "Palæontology," by Richard Owen, F.R.S., etc.

† Existing sponges are divided into *horny*, *flinty*, and *limy*.

leaving a botryoidal, or stalactical cavity. The cup-shaped sponges are almost always more or less enveloped with flint, which invests the stem and lines of the interior, leaving the rim exposed. The sponges of the Yorkshire chalk are of a different character; some are elongated and radiciform, others horizontally expanded; but they contain comparatively little silica."

There have been 427 species of fossil sponges enumerated, but this is considered as probably only a small proportion of the actual number in museums and private collections.

Referring to fossil sponges, Professor Phillips says, "It deserves attention that the interesting remains of the *spongiæ* are nowhere so well developed as in England, and perhaps nowhere in England so well as in Yorkshire. On the shore, near Bridlington, they lie exposed in the cliffs and scars, and being seldom enclosed in flint, allow their organization to be studied with great advantage." And, in reference to the fossil character of the chalk in Yorkshire, the same author remarks: "The fossils, however, which are known to occur in the chalk of Yorkshire, are precisely those which have always been noticed by geologists as of the most extensive occurrence in that stratum. The ananchytes, spalangi, inocerami, and belemnites, are precisely the shells which have been long since pointed out by Smith, Webster, Parkinson, and Mantell, as characteristic of the English chalk, and the same species have been recognized by Brogniart in the same stratum, not only over the wide surfaces which it occupies in France, but in the Netherlands, along the shores of the Baltic, and in Poland."

Among the fossil shells of the cretaceous formation are the *Ammonites* (the form of which is represented on the title-page), possessing the most beautiful and varied forms. They take their name from their resemblance to the horns on the head of the statue of Jupiter Ammon. These mollusca existed in great

abundance during the cretaceous age, but never reappeared after that period.

Fossil intestines, called *cololites*, and which have been confounded with *coprolites* (the fossil dung of extinct reptiles), have been found in beds of lithographic limestone at Solenhofen, a village near Munich.

Many highly interesting fossil vegetable remains of the cretaceous age have been found in the various strata, including ferns, palms, conifers, cicadæ, arborescent ferns, etc. Some very fine specimens were obtained from the "Iguanodon Quarry," as it is called, after the remarkable fossil lizard, discovered by Dr. Mantell; and our National Museum contains many other specimens from Hastings, Portland, Sheppy, etc.

The geological discoveries connected with the cretaceous age prove that at certain periods of this wonderful formation, the land was clothed with abundant vegetation; and indeed the magnitude of such herbivorous reptiles as the iguanodon and *hylæosaurus*, for example, would indicate that their food must have been prolific.

Fossil antlers and bones of the roebuck were found in limestone caverns in the neighbourhood of Stoke-upon-Trent, and other similar remains have been discovered in Berkshire and other counties in England.

The marvellous abundance of the shells of foraminifera, which enter so largely into the composition of all the sedimentary strata, as chalk and limestones, prompted the great naturalist, Buffon, to say that "the very dust had been alive." Not only do they constitute a greater part of huge mountain ranges, but it has been proved by the deep-sea soundings made by the Atlantic Cable Company that the bed of the ocean, at a depth of more than two miles, is composed almost entirely of calcareous shells of different species of foraminifera.

If a piece of chalk be worked up with water, the finer particles will remain in suspension after a few moments' repose; and if the liquid portion be now poured off, a sediment will be found at the bottom of the vessel, which consists almost entirely of foraminated shells. By repeatedly washing this deposit in the same way, so as to remove all the finer particles, the shells will be in a separated condition, and may then be examined by a microscope. The foraminifera also occur in marbles and in hard limestones.

Dr. Page gives the following as characterizing the cretaceous formation:—

“ The organic remains found in the cretaceous system are, with a few exceptions, eminently marine, comprising fucoids, sponges, corals, star-fishes, molluscs, crustacea, fishes and reptiles. As might be expected, fossil plants are comparatively rare in the British chalk-rocks, and these for the most part drifted and imperfect fragments; but among the cretaceous beds of other regions, seams of lignite and coal are by no means unfrequent. The marine species are apparently allied to the algæ (seaweeds) *conservæ*, etc., and are termed *chondrites* and *conservites*. The terrestrial types are fragments of tree-ferns, cones of coniferous trees, cycadites and zamites, and are known by such names as *pinites*, *strobilites* (*strobilus*, a fir-cone), *carpolithes* (*carpos*, a fruit) and *zamiostrobus*. Of the animal remains, which are in general beautifully preserved, and to be seen in almost every collection, we can only notice one or two examples under each order or family. Of spongiform bodies we have the characteristic *choanites*, *spongia*, *scyphia* and *ventriculites*. Of zoophytes and polyzoa there are numerous *astrea*, *alveolites*, and *orbitolites*, *flustra* and *retepora*. Of echinoderms, or sea-urchins, there are many species in every state of perfection, as *cidaris*, *galerites*, *spatangus* and *micraster*.

Of foraminiferous shells, which compose in great part the chalk strata, there are *rotalia*, *dentalina*, *textularia*, etc. Of annelids, abundant *serpularia* and *vermicularia*; and of crustaceans, species of lobsters, *astacus*; and of crabs, *dagurus*.

"The remains of testacea, or shell-fish, are extremely numerous, and in such a state of perfection that the conchologist can at once assign them a place in his classification. Of the characteristic bivalves may be noticed *arca*, *cardium*, *trigonia*, *gryphæa*, *inoceramus*, *ostrea*, *pecten* and *terel-ratula*, with the curious massive shells, *hippurites* and *diceras*. Among the univalves, or gasteropods, *cerithium*, *rostellaria*, *dentalium*, and *natica*, are typical and characteristic. The chambered shells also appear in vast profusion, and in highly curious forms, as compared with those of the earlier formation. Of these, the coiled-up *ammonite*, the dart-like *belemnite* (the thunderbolts of the English peasant), the hook-shaped *hamite* (*hamus*, a hook), the boat-shaped *scaphite* (*scapha*, a skiff), the rod-like *baculite* (*baculus*, a staff), and the *nautilus*, are the most frequent and typical."

CHAPTER IX.

Lithological Arrangement of the Cretaceous System — Dr. Page's Observations on Classification.

IN a former chapter the cretaceous system was considered from its *zoological* characteristics; that is, its various stages were determined by the special *fauna* which marked each period of this great formation. When considered

From *lithos*, a stone, and *logos*, a discourse.

however, the group of strata which constitute the cretaceous formation, in the south of England, are generally classified as follows:—

Upper white chalk, with and without flints.

Lower chalk, without flints.

Chalk marl.

Upper greensand.

Gault (a bluish clay, sometimes of a marly character).

Lower greensand.

Beneath these strata is the *Wealden* group, comprising the Weald clay, the strata of Tilgate Forest, Sussex, rendered famous by Dr. Mantell's remarkable discoveries—the Purbeck limestone and clay strata, etc. The Wealden group is a fresh-water formation, and, according to that great geologist, was evidently the delta* of some ancient river. It is "characterized by an abundance of the remains of enormous and peculiar reptiles, the *Iguanodon*, *Hylæosaurus*, *Megalosaurus*, *Plesiosaurus*, *Crocodile*, etc.; of terrestrial plants, fresh-water mollusca, and birds."

It will thus be seen that the cretaceous system includes many other deposits besides chalk, but although the various strata possess entirely different characteristics, *lithologically*, they agree in the character of the organic remains which have been recovered from them, which has induced geologists to assign to this formation one epoch or age—the duration of which is as incalculable as the grains of sand upon the sea shore. "Taken as a whole," says Dr. Morton, "the chalk formation may be described as extending over the greater part of the British Islands, Northern France, Germany, Denmark,

* From the Greek Δ (delta) being the form of land enclosed by the mouths of rivers, as the delta of the Nile.

Sweden, European and Asiatic Russia, and of the United States of North America ;" and Dr. Mantell states that over this vast extent the organic remains of the chalk maintain certain general characters sufficiently obvious to determine the nature of the formation. "Whether imbedded in pure white limestone, coarse sandstone, blue clay, loose sand, or compact rock, the fossils consist of the same species of shells, corals, sponges, echinites, belemnites, ammonites, and other marine exuviae ; fishes, reptiles, wood, and plants."

One of the most remarkable series of limestone strata occurs in the Isle of Portland, from whence the well-known building stone, bearing its name, is obtained. The Portland oolite (a marine formation), forms the lower stratum of this series, and is extensively quarried for architectural and other purposes. Above this is a bed of fossilized vegetable matter, surmounted by a thick stratum of freshwater limestone ; and above this again a petrified forest was discovered, in which trees and plants, many of them retaining their natural position, as though they had been petrified while still growing. Above this bed of vegetable remains is another stratum of fresh-water limestone, then a layer of clay, and on the top of this is a third stratum of fresh-water limestone, the whole series being capped by vegetable soil. Thus we see that in this interesting series there are no less than three strata of fresh-water limestone, two consisting of vegetable remains, and one of clay. These strata, which rest upon the oolitic limestone, form the lowest portion of the Wealden formation, and are consequently situated below the chalk series.

Referring to the classification of the numerous and varied strata which form the earth's crust, Dr. Page observes, "The principal guides to geological classification are, order of superposition among the strata, their mineral composition, and the nature of their imbedded fossils. The most superficial observer

must have noticed the different aspects of the rocks in different districts, and a little closer inspection will enable him to detect that one set lies always beneath another set, and that, while certain shells and corals are found in the lower series, the upper series may contain only the remains of terrestrial vegetation. Thus, in sinking a shaft in the neighbourhood of London, we should pass through thick beds of plastic clay, layers of sand, and strata of water-worn flint gravel; at Cambridge we would pass through strata of chalk; in the east of Yorkshire through strata of fine-grained sandstone and soft yellowish limestone, called oolite; at Newcastle through strata of shell, coal, and coarse-grained sandstone; in Forfarshire through strata of red and greyish sandstone and conglomerate; while, on the flanks of the Grampians, we would pass through beds of roofing slate and hard crystalline schists. On a minuter inspection of these strata, we would find that one series lay beneath, or was older than another series; that the chalk, for example, lay beneath the clays of London; that the yellow limestone of York lay beneath the chalk; that the coals of Newcastle were deeper seated than the oolite of York, and the red sandstone of Forfar still deeper than the coal-bearing strata."

When the fossils contained in the different strata are examined, it is found that each set of strata is characterized by the remains of peculiar animals and plants. In some are marine shells and corals; in others enormous reptiles and fishes, while in some strata are the remains of terrestrial vegetation, each set of strata marking a distinct epoch of time. Thus "we would soon be enabled," says Dr. Page, "to identify the chalk strata of Cambridge with those of Kent, the oolites of York with those of Bath, the coal measures of Newcastle with those near Glasgow, and the slates of the Scottish islands with

those of Cumberland and Wales. As with the rocks of Britain, so with those of every country investigated by geologists ; and thus they have been enabled to arrive at a pretty accurate classification of the stratified rocks, both in point of time and mineral character." This clear exposition of the principles upon which geological arrangement or classification has been arrived at by our great observers, will guide the student who may desire a more intimate acquaintance with the charming science of geology than can be conveyed within the limits of the present work, and to whom we would recommend the perusal of Dr. Page's admirable "Text-Book of Geology."

CHAPTER X.

Evidence of Floating Ice in the Sea of the White Chalk in England—Views of Sir C. Lyell and Mr. Godwin-Austin—Spring-water of the London Basin—Formation of Chalk from Coral.

It had often puzzled geologists to account for the presence, in chalk, of stones and pebbles, wholly different in character from the flints which occur in the upper chalk formation. That their presence was *accidental*, and not a necessary part of the great cretaceous system, was evident from the general character of this formation. Remarking upon this subject, in connection with the origin of chalk, Sir C. Lyell says :—" The homogeneous character of the white chalk, or upper portion of the great cretaceous formation throughout a large portion of Europe, is now explained by the discovery that it is made up of the remains

of *foraminifera* ;* while the silicious portions have been derived chiefly from plants called *diatoms*. It was ascertained, when soundings were made for the electric telegraph, that calcareous mud of a similar character and origin is now forming over vast areas in the depths of the Atlantic.

"The general absence from the white chalk of sand, pebbles, drift wood, and other signs of neighbouring land, is thus accounted for, but the occasional discovery of single and perfectly isolated stones, usually consisting of quartz and green schist, in the south-east of England, has naturally excited much surprise. In what manner could such stones have been carried far out into an open sea, so as to fall to the bottom without any admixture of other foreign matter? I formerly endeavoured to explain the enigma by referring to a fact observed by Mr. Darwin, namely, that stones of considerable size are occasionally entangled in the roots of floating trees, and transported to great distances in mid-ocean. One of these, as big as a man's head, was conveyed in this way six hundred miles to Keeling Island, a small ring of coral in the Indian Ocean." He then goes on to explain that the seaweed called *kelp*, which, being uprooted, frequently carries along with it, from shallow water, pebbles and earth derived from the shore on which it grew. After reviewing all the facts which have been observed, however, he entertains the view of Mr. Godwin-Austin, that there are cases in which the transportation of pebbles, etc., must be attributed to the agency of ice.

"Thus, for example," says Lyell, "in 1857 there was found at Parley, near Croydon, in the body of the white chalk, a group of stones, the largest of which consisted of syenite, a rock

* Microscopic shells, the chambers of which are united by a small perforation or *foramen* (opening).

composed of augnite and felspar. This block had been broken up by the workmen before it was examined by any scientific observer, but the largest of the fragments was ascertained to be twelve inches in diameter in two directions; and to weigh upwards of 24 lbs. It was surrounded by granitic sand and pebbles of green stone, and its dimensions rendered the hypothesis of transportation by drift timber inadmissible; there was, moreover, a total absence of carbonaceous [woody] matter, such as might have been looked for if a water-logged tree had sunk on the spot."

Mr. Godwin-Austin suggested that the pebbles and sand must have been frozen into coast-ice, and this carried out to sea; and, from a mineralogical point of view, the stones presented just such an assemblage as may be found on a beach on the coast of Norway. As to the degree of cold necessary to form such coast-ice, it may not, he imagines, have exceeded that sometimes experienced in our own time on the East Coast of England, from which ice has lifted and floated away with far greater weights than the stones above referred to.

Lyell mentions another example of a rounded block weighing over thirteen pounds, which had been observed by Mr. Catt in the "chalk with flints," in a pit near Lewes, attached to which were several fossil species.

Spring-water of the London Basin.—Prior to the construction of the New River, and the establishment of our great water companies, the inhabitants of London and its environs were chiefly dependent upon springs, or wells sunk below the London clay, for their water supply; and it is interesting to know, from geological observation and chemical analysis, what was the character of the water, and the causes which might effect the proportions of the soluble constituents with which this water is, always more or less, associated.

Sir H. De la Beche* makes the following observations on the source and character of the water obtained from beneath London. "The waters rising from the chalk at the Artesian well in Trafalgar Square, London, and which are obtained from their dissemination in that rock, show that in 68·24 grains of solid matter in an imperial gallon 18 grains are composed of carbonate of soda, while the carbonate of lime contained among the solid matter above-mentioned only amounts to 3·255 grains, and thus the waters, resting to a certain extent stagnant in the chalk beneath London, with its thick covering of (London) clay, exhibits a very different character as to the substances in solution than in the springs which flow out of the chalk on the surface where that rock arrives at or adjoins it.

"In the cases of soluble mineral matter disseminated in the rocks, such as the chalk beneath London, it should be borne in mind that when there is a movement of the contained water among their pores or fissures to supply that raised to the surface by pumping, or rising from boring and overflowing, the original condition of the somewhat stagnant dissemination becomes changed by the amount of water thus required, so that when many wells reach into the chalk, as beneath London, a movement of water amid the body of that rock is occasioned towards the various wells, which would not have taken place under ordinary natural circumstances."

The following analysis of the waters of Trafalgar Square, London, by Messrs. Abel and Bowing, will show the number of substances and their proportions in an imperial gallon:—

Carbonate of lime	.	.	3·255 grains.
Phosphate of lime	.	.	0·034 "
Carbonate of magnesia	.	.	2·254 "

* "The Geological Observer," by Sir H. De la Beche, F.R.S., etc., 1851.

Sulphate of potash	.	.	13·671	grains.
Sulphate of soda .	.	.	8·749	„
Chloride of sodium (common salt)	.	.	20·038	„
Phosphate of soda	.	.	0·291	„
Carbonate of soda	.	.	18·049	„
Silica	.	.	0·971	„
Organic matter	.	.	0·908	„

Formation of Chalk from Coral.—Mr. Darwin drew attention to the fact that the coral mud at one spot among the reefs of the Pacific, when dried, presented much the appearance of chalk, and it also suggested itself to Mr. Dana by the mud in the lagoon of Houden Island. “Still it does not explain the main point,” he says, “for under all ordinary circumstances this mud solidifies into compact limestone instead of chalk. This appears, moreover, to be the result which should be expected. What condition then is necessary to vary the result and set aside the ordinary process? * The bed of chalk referred to was not found on any of the coral islands, but in the elevated reef of Oahu, of which reef it formed a constituent part. It is twenty or thirty feet in extent, and eight or ten deep; the rock could not be distinguished from much of the chalk in England; it is equally fine and even in its texture, as earthy in its fracture, and so soft as to be used on the black board in the native schools. Some imbedded shells look precisely like chalk fossils.”

Importance of Microscopical Examination.—Some limestones

* Is it not possible that during tempestuous periods the deposit of carbonate of lime made by living polypes for their abodes, may be disturbed and washed away before it has time to harden into coral; and that in this way calcareous deposits would occur which, although resembling chalk in appearance and chemical composition, would yet differ from it in not consisting chiefly of organic remains?

require very careful examination in order to ascertain their mode of formation. Thus it has been observed that beds presenting the appearance of organic remains to the naked eye may yet be proved to be almost wholly composed of them when the microscope is employed and due precautions taken. In this manner many beds of the mountain limestone series of the British islands have been found replete with the remains of life where none were at first suspected. Even when, upon exposure to atmospheric influences, fossils of far larger dimensions, readily visible to the naked eye, and extending to half an inch or more in length and breadth, are found in fair abundance, it sometimes occurs that the ordinary fracture of the limestone bed may not readily show them. We do not here include remains of encrinites, echinites, and some other fossils which, from their rhomboidal fracture, a little practise will enable an observer readily to distinguish, but others where they are far from being easily detected. The most beautiful shells will occasionally thus present themselves upon searching a weathered surface, not a trace of which can be obtained by ordinary observation,—*De la Beche*.

CHAPTER XI.

**Carbonate of Lime and Phosphate of Lime in Bones—
Superphosphate of Lime as Manure — Guano — Rotten
Stone: its doubtful origin.**

THE solid structure of the bones of animals is due to the very large proportion of phosphate of lime and carbonate of lime which they contain. In the bones of the ox there is found, by

analysis, 57·35 per cent. of phosphate and 3·85 of carbonate of lime. The former is the most important constituent, since it is from this source that *phosphorus* is obtained, and from which also a valuable fertilizing compound is prepared, termed *superphosphate of lime*.

When bones, after having been boiled to remove the fatty matter and gelatine, are calcined, the *bone-ash*, as it is called, is first crushed small and then digested with diluted sulphuric acid for several days with occasional stirring. Superphosphate of lime is thus formed, and if this, after being mixed with water and dry earth, is spread on soil it forms an excellent manure. Coprolites (the fossil dung of extinct carnivorous reptiles) contain a large proportion of phosphate of lime, and these, after being ground in a mill, are treated with an equal weight of oil of vitriol, by which superphosphate of lime is formed, and which is much used as an artificial manure, especially for corn and grass.

The valuable native manure known as Guano, or *Huano*, as the Peruvians call it, owes its marvellous fertilizing properties greatly to the salts of ammonia which it yields. It contains, however, a considerable proportion of phosphate of lime, which is one of its most important fertilizing constituents. Guano is the fossil remains of the dung of sea-birds, but more especially, it is believed, of the common penguin; and it is frequently intermingled with their skeletons and egg-shells. It is principally obtained from the rocks and islets of the coasts of Peru and Bolivia. It has been found in depths ranging from 40 to 120 feet. At one period it was very extensively imported from the island Ichaber, on the west coast of Africa. Guano is very variable in composition, but the following analysis of a sample of Peruvian guano will give some idea of the constitution of this important natural manure:—

• Organic matter, containing ammonia	. 53'7
Phosphate of lime and magnesia .	. 23'54
Carbonate of lime . . . . .	. 4'18
Common salt and sulphate of soda	. 4'63
Sand . . . . .	. 1'39
Water . . . . .	. 13'09

The chief constituent of the shells of all shell-fish, including the lobster, crab, oyster, mussel, periwinkle, etc., is carbonate of lime, with, sometimes, a little phosphate of lime. When calcined, they form quicklime, which is known under the name of *shell-lime*. In former times, powdered crab's claws, oyster shells and corals were employed in medicine as an antacid. The solid matter of egg-shells is also carbonate of lime.

Rotten-stone, or *Tripoli*, is a mineral substance of very variable composition, and its origin has been the subject of much controversy. According to some observers, it is of animal origin, and consists of the skeletons of *infusoria*. It is stated that under the microscope these can be seen with such great distinctness that there is no apparent difference between the living and petrified species. The analysis of one specimen showed 81 per cent. of *silica*, and 1'5 of alumina; and another, from Derbyshire, examined by Mr. Phillips, contained 86 per cent. of alumina and 4 of silica, which led him to conclude that this substance was due to the decomposition of slate rocks. Professor Johnstone, however, is of opinion* "that the rotten-stone was not the result of the decomposition of the shale of Derbyshire, but of the veins of black marble of the country, which had undergone a great change. In proof of this assertion, he produced specimens which he found in black marble, with the merest coating of rotten-stone upon them, whilst others were

* *The Chemist*, Vol. I, New Series, p. 63. 1854.

half rotten-stone and half black marble. The decomposition had been effected by dissolving the lime out of the rock, and not the rotting of the strata ; this substance can be produced by dissolving the lime out of limestone, by bringing weak acids to bear upon it. This proved that there must necessarily exist in the soil some acid which dissolves the lime with which it comes in contact. Farmers would therefore see the necessity of adding lime to their land from time to time, because the lime kept continually washing away by the waters of heaven falling on it, and extracting from the rotting roots of the earth an acid [humic acid?] which had a powerful effect, not only on lime but on other mineral structures as well."

The remarkable difference in the composition of the rotten-stone of Bohemia, Corfu, Isle of France and that of Derbyshire, would tend to prove that the latter has a different origin to the former, and that the term rotten-stone is frequently applied to a substance wholly different from the genuine *tripoli*, which is so famous as a polishing material for silver, brass, and some other metals and alloys.

Gypsum, or native sulphate of lime, is much used as a fertilizer for certain soils, either alone, or in combination with other substances. For example, calcined gypsum, bone-dust, and sulphate of ammonia ; or gypsum, bone-dust, wood ashes, common salt and crude potash in various proportions form artificial manures for certain crops.

• CHAPTER XII.

**Quicklime, how prepared—Lime-burning—Lime Kilns—
Uses of Lime in the Arts.**

Lime, or *quicklime*, is prepared from various kinds of chalk and limestone, but those which are most free from silica, marl and clay are preferred. To convert chalk into quicklime, it must be deprived of its carbonic acid and moisture, and this is effected, as before observed, by calcination. *Lime-burning*, as it is termed, is sometimes conducted, upon a small scale, in a kiln formed at the bottom of the chalk pit or quarry, or at some convenient spot contiguous to it. A simple form of kiln adopted by small lime-burners is built of brickwork, in the form of an inverted cone. At its base a fire-grate is fixed, and a little above this, on the right or left, as may be most convenient, is a side door by which the finished lime is withdrawn. The fire being kindled, alternate layers of coal and chalk (the latter being previously broken into lumps of convenient size) are introduced into the opening at the top, until the kiln is full, and as the material sinks down during the progress of the calcination, fresh layers of fuel and chalk are thrown in from the top and piled up to the height of several feet. The well burnt lime is raked out from time to time by the side door, and a fresh supply of materials added as before. In this way the operation is kept up continuously day and night throughout the year. This is called a *drau-kiln*, from the fact that the lime is drawn or raked out during the process of calcination, which occupies about forty-eight hours. About one bushel of coal is consumed for every three bushels of lime produced.

For making lime upon an extensive scale very large kilns, called *shaft-kilns*, are employed, and the calcination is effected by means of furnace fires so constructed that the heat from them passes through the limestones, which are placed in a shaft in the centre of the structure. The kiln is set in operation by first filling the shaft with limestones to the level of the lower furnaces, when the fires are kindled and kept burning until the calcination is complete. Fresh quantities of limestones are now let down by buckets from the top—not thrown in as in the former method—until the shaft is quite full and the limestones are piled up to the height of several feet. The doors of the lower furnaces are now *luted*, so as to stop the draught, and the upper furnaces are then kindled and the fires kept up until the upper limestones are well burnt, when the lime beneath the level of the fires is drawn out by the discharge doors. While this is being done, the upper contents of the shaft gradually sink down, and the space is again filled by fresh limestones and piled up as before. In this way the operation of lime-burning proceeds uninterruptedly. The calcined lime is drawn from the kiln about every twelve hours, when about two tons and a half are obtained from each kiln. Sometimes these kilns are arranged in a group of three, by which three times the produce is obtained.

In calcining lime, it is important that the limestone should be moist, since it is found that the vapour of water which is given off by the heat assists the expulsion of the carbonic acid, upon which the *causticity* of the lime depends. Sometimes it is the custom to moisten the stones before calcining them, but this necessarily involves the consumption of a larger amount of fuel. It is considered a better practice to introduce a jet of steam into the kiln during the process of calcination. Quicklime is more readily prepared from white*chalk than from compact

limestone, since it is of a more porous character, and always contains sufficient moisture to aid the escape of the carbonic acid.

Lime is largely used in agriculture as a fertilizer for certain soils which are known to be free from or contain but little calcareous matter. Indeed it is well known that no soil is fertile which does not contain a very considerable proportion of calcareous earth, or some salt of lime. Hence it is that lime, superphosphate of lime (prepared from bones and oil of vitriol), gypsum (sulphate of lime), soapmakers' waste—the refuse carbonate of lime resulting from the manufacture of caustic soda leys—and any other cheap and available source of lime is employed by agriculturists whose land is destitute of this important constituent.

In the purifying of coal gas for illumination, lime has been largely employed for the purpose of removing carbonic acid and sulphuretted hydrogen, by which it is contaminated when it passes over from the retorts.

The caustic leys used in the manufacture of soap are produced by mixing solutions of alkalis (carbonate of soda or potash) with lime, whereby they are deprived of their carbonic acid, and converted into *caustic alkali*, while the lime once more becomes carbonate of lime.

Lime is also used for removing the hair from animal skins, or hides, previous to their being subjected to the process of *tanning*.

In the manufacture of ammonia from the ammoniacal liquors of the gas works, the liquor (which contains carbonate of ammonia in solution) is first treated with sulphuric or hydrochloric acid, which converts the carbonate into sulphate or hydrochlorate of ammonia, and these are afterwards treated with *milk of lime* (that is, lime mixed with a moderate quantity of water) which liberates the volatile alkali (ammonia), and this

is afterwards obtained in the form of liquid ammonia, by distillation. Sulphate of lime or chloride of calcium (according to which acid has been employed in neutralizing the gas liquor) remains in the still or retort.*

When lime is mixed with white of egg (albumen) it forms a very powerful cement for uniting fragments of broken china, porcelain, or earthenware.

It is a remarkable fact, which was established by Dr. Dalton, that lime dissolves more freely in cold than in hot water, and Mr. R. Phillips ascertained that water near the freezing-point took up nearly twice as much lime as boiling water.

A pint of water at 32° Fahr. dissolves 13·25 grains of lime.

„	„	60°	„	„	11·6	„	„
„	„	212°	„	„	6·7	„	„

Lime water is used in medicine as an antacid, in cases of dyspepsia, and when taken in milk greatly assists the digestion of that nutriment by weak stomachs. Lime-water and olive oil or linseed oil in equal parts, briskly shaken together, form a *lime soap*, which is used as a liniment in cases of burns and scalds, and for this purpose it is used at the Carron iron foundry—hence it is sometimes called *Carron oil*.

Lime is also employed in the manufacture of *stearine*, for candles. Melted tallow and hydrate of lime (slaked lime) are boiled together, by high pressure steam, for several hours, by which operation a *lime soap* is formed. Dilute oil of vitriol (sulphuric acid) is then added to the soap, with heat and brisk stirring, when the lime is converted into *sulphate of lime*, which is allowed to subside, and the *stearic acid* formed is transferred to another vessel and allowed to cool, after which it is cut into

* Further information upon this subject is given in "The History of a Lump of Coal."

shavings by machinery, and these are put into canvas bags and subjected to powerful pressure, when the liquid portion (*oleic acid*) of the fatty matter separates, and the solid stearine remains in the bags in the form of hard cakes. This operation being repeated, the result is hard and dry stearine, from which candles of the finest illuminating power are made.

Although there are many other purposes to which lime is applied—in the clarification of cane sugar, for instance—it is hoped that the information given will be sufficient to demonstrate its great usefulness in the arts.

CHAPTER XIII.

Cements made with Lime—Portland and Roman Cements—Cement Materials.

WHEN lime, sand, and water are worked up into a thick pasty mass, as in the ordinary process of making bricklayers' mortar, the resulting mixture gradually hardens, until, after a lengthened period, it becomes, literally, "as hard as a stone." Again, when lime and clay are mixed together in certain proportions under water, and the muddy mass thus formed afterwards dried, calcined, and powdered, a material is obtained which has the property of hardening under water, and which from this cause is termed *hydraulic cement*. The famous *Portland cement* is made in this way.

In selecting the materials for making Portland cement, chalk containing moderate proportions of silica and alumina is preferred, and argillaceous river mud, or clay containing only a small percentage of oxide of iron is chosen. The proportions are (about)

chalk eighty parts, clay twenty parts. These ingredients are intimately mixed together under water, and great care is taken that no lumps of either chalk or clay are left in the mud when the mixing is completed. The mixture thus formed is run into large pits and allowed to remain until the solid matter has deposited, when the water is removed by pumping. The mud is afterwards dried, and is then burned in a suitable kiln. The calcined material is afterwards ground and sifted, and the powder carefully packed in casks for the market.

Cements are also made from a mixture of clay and limestone worked up into a paste, which is then moulded into bricks, and these, after being dried in the air and calcined, are ground and sifted as before. The *wet* method given above, however, produces a superior cement, and is generally adopted in this country.

Good Portland cement, after being worked up into a paste with water, sets very quickly, and after a few weeks it becomes exceedingly hard, especially under water.

Roman cement.—The genuine Roman cement is made from a volcanic substance called *puzzolene* or tufa stone, and is composed of silica, alumina, lime, magnesia, oxide of iron, etc. The stone is first ground and sifted, when it is called *trass*, and to this lime and sand are added as required. This cement does not set so quickly as the former, but acquires considerable hardness after a few days.

All limestones which contain from twenty to thirty per cent. of silica and alumina will make good hydraulic cement, after being calcined at a moderate heat, and then ground and sifted as before, but the principal mineral used for this purpose in England is *septaria* or *cement stone*, a species of ferruginous marl, or clay ironstone, which occurs in single nodules in beds of clay, in the upper division of the lias formation, and in the clay strata above

the chalk. These so-called cement stones are also found on the coasts of Kent and Yorkshire, and on the Isles of Thanet and Sheppy. These nodules are first burnt in a conical kiln, with coal, in the same way as in ordinary lime-burning, great care being taken that the heat is not too great, otherwise partial fusion would take place which would render the material useless for cement. When sufficiently roasted, or calcined, the stones are finely ground and sifted, and the powder at once packed in casks to preserve it from the air and moisture.

In the year 1850, Mr. Gibbs obtained a patent for improvements in the manufacture of hydraulic cement, by which an article of excellent quality is produced. The materials he employed were obtained "from the vast beds of (natural) argillaceous marls and marly limestones, or marlstones, which contain the due admixture of lime, silica and alumina, from which hydraulic cements and artificial stones may be manufactured." He obtains his materials from "the chalk formation, the Wealden formation, the Purbeck beds, the lias formation, the mountain limestone, and the lowest strata of the coal measures." The various materials were selected according to the kind of cement required, and kiln-burnt, ground and sifted in the ordinary way, but marls and limestones he directs to be "first dried in kilns or ovens, at a heat fit for baking, until all moisture be driven off, and that then the calcination be prolonged as much as possible—the heat being kept as low as is only just sufficient to effect complete calcination—this being indispensable to avoid the commencement of vitrification, which would destroy the adhesive properties of the cement."

It has been proved that a very good artificial stone may be made by impregnating dry chalk with a solution of *silicate of potash* (soluble glass). The chalk may either be in its natural state or worked up into a paste, and formed into blocks; it is

alternately dried in the air and soaked in the silicate solution until it acquires the necessary hardness. Chalk treated in this way assumes a smooth appearance, with a compact grain, and is susceptible of a high polish. The hardness is at first superficial, but in time it penetrates to the centre, even if the blocks are of considerable thickness.

The conversion of soft chalk into silicious and compact limestone, which is thus effected artificially, explains in some degree the operations which have taken place in the natural formation of silicious limestones in which the induration is clearly due to the chemical combination of the silica with lime, alumina, etc.

There are many other processes for making hydraulic or water cements, and artificial stone, but the processes briefly described will show the principle upon which such cements are formed--the calcination of substances containing (essentially) lime, silicious matter, and alumina--the latter substances being the constituents of clay, which owes its colour to the presence of oxide of iron.

The *hardening* of hydraulic cements is due to chemical action which takes place when the calcined material is moistened with water. The *silica* (which is also called *silicic acid*, from its combining with earthy and alkaline bases to form salts) combines with the lime, alumina, and magnesia contained in the cement, forming *silicates* of those bases, as silicate of lime, silicate of alumina, etc., and thus an artificial stone is produced which possesses great durability and extreme hardness.

It will be readily understood, therefore, that when lime (oxide of calcium) is mixed with sand (silica) and water, as in making ordinary mortar, the *setting* and subsequent hardening of the material arise from a chemical change which gradually takes place in the moistened mass. *Stone'lime*, which is made from a

less pure limestone than chalk, is preferred for mortar making, inasmuch as it contains small quantities of silicious matter and alumina. Mortar should always be made with river sand, in preference to either road drift or sea sand—unless the latter be well washed in fresh water; and when it is borne in mind that mortar is intended to *cement* or *bind* bricks together, and not merely to keep them in position, it would be well if district surveyors, when “jerry” buildings are in course of erection, were to examine the materials with which this important cement is made. That it is frequently made from worthless and unsuitable materials, we have had many opportunities of witnessing, as indeed must have been the case with many others.

CHAPTER XIV.

Chloride of Lime, or Bleaching Powder: its Manufacture and Uses.

ONE of the most important purposes to which lime is applied in the arts is in the manufacture of bleaching powder, or, as it is technically termed, *chloride of lime*.* The bleaching power of chlorine gas had long been known to chemists, and its utility in the arts, as a decolouring or bleaching agent, fully recognized, but it was not until Mr. Charles Tennant, of Glasgow (in 1798), discovered a convenient method of combining this gas with lime, that its usefulness could be fully developed. His process consisted in passing chlorine gas through lime-water, which,

* Or hypochlorite of lime.

absorbing the gas in considerable quantity, thus formed a powerful and convenient bleaching liquid. An important improvement in this process, however, was patented in the following year by Mr. Makintosh, a member of the Glasgow firm, and this consisted in passing chlorine into an air-tight chamber containing dry slaked lime, which readily absorbs this gas.

In manufacturing bleaching powder upon a large scale, a very good quality of lime is employed. The lime is first spread upon a flat surface, and is then sprinkled with water from a watering-can, when, after a few moments, heat is generated, and steam given off from the lumps, and soon after the lime crumbles into powder. This *hydrate of lime* is now passed through a sieve, to keep back stones or unslaked lumps, and is then spread over the floor of a lead-lined chamber to the depth of about six inches. These chambers are generally about sixty feet long, thirty feet wide, and five feet high.

The chlorine gas is generated in leaden retorts, from a mixture consisting of peroxide of manganese, sulphuric acid, common salt, and water, assisted by steam heat. The gas is conducted by piping through a stoneware bottle to free it from moisture, and from thence it passes to the lime chamber; being considerably heavier than atmospheric air, the gas quickly descends to the lower part of the chamber, and becomes gradually absorbed by the lime. When it is known that the lime is sufficiently saturated with the gas, the chamber door is opened, and the bleaching powder raked towards it, and dry casks placed ready to receive it. A workman, having his mouth and nose previously covered by a piece of wet flannel tied over them, now enters the chamber, and shovels the material into the casks, which is called *packing*. Before this operation is commenced, however, the bleaching powder is allowed to cool, and care is

taken not to expose it to the rays of the sun, otherwise it would undergo decomposition.

Good chloride of lime usually contains from thirty-five to thirty-seven per cent. of chlorine. It is very extensively used (in solution) for bleaching the "*half-stuff*," or *pulp*, in paper-making, and it is to this important bleaching agent that we are chiefly indebted for our abundance of cheap white papers, the manufacture of which does not, as was formerly the case, depend solely upon the fibre obtained from cotton rags. Indeed, during the past thirty years innumerable vegetable fibres have been introduced into the manufacture of paper, including the now famous *Esparto grass*, which is one of the most valuable and extensively-used materials of its class. In the year 1853, the author's father introduced his process for making paper from *wood fibre*, which is now extensively adopted in many countries, but more especially in the United States of America.

Chloride of lime is also extensively employed in the "bleach works" for whitening cotton goods or calicoes after they have passed through the weaving operations. A very weak solution of the bleaching powder is employed, otherwise the delicate fibre would be impaired. The cotton pieces, which are about thirty yards long, are tacked together endwise, by machinery, and after *singeing*, *crushing*, *lucking*, or boiling in milk of lime, and several other operations, they are "chemicked," as it is called, which consists in soaking them for a certain time in a weak solution of chloride of lime. The cloth is then "washed," and after boiling in a weak solution of soda, is again washed, and once more "chemicked" as before, after which it is again washed, and passed through a weak solution of hydrochloric acid, and finally washed and dried over steam-heated cylinders. It is then ready for the subsequent processes of *dressing* and *finishing*.

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As a *disinfectant* and *deodorizer*, chloride of lime holds a high position ; and although many other substances are employed for these purposes, it is doubtful whether they can be as fully relied upon.

CHAPTER XV.

**Preparations made from Chalk—Whiting—Prepared Chalk—
Precipitated Chalk—Salts of Lime—Chloride of Calcium
—Sulphurets of Calcium—Acetate of Lime—Chromate
of Lime.**

ONE of the most extensive uses of white chalk is in the manufacture of *whiting*, an article much employed in white-washing, in the manufacture of paper-hangings, or wall paper, and for many other purposes in the arts. In the preparation of whiting, the chalk is first ground in a mill, with water, after which the creamy mass thus produced is largely mixed with more water, and after a few moments' repose, the upper portion, containing the finer chalk particles, is run off into large tanks and allowed to settle. The clear water is then run off, and the white mass at the bottom of the vessel is afterwards collected, drained, and made into oblong cakes, which are then dried sufficiently to be marketable.

When mixed with size and water, it constitutes ordinary "whitewash," and is employed for giving a clean white surface to ceilings and walls.

Spanish white is the name given to a cheap pigment, which is nothing more than whiting carefully prepared from chalk.

The *prepared chalk* of the druggist is obtained in much the same way as above, except that greater care is observed to

collect only the very finest particles of the chalk that float in water after the coarser particles have subsided.

Precipitated chalk is prepared by adding to a solution of chloride of calcium, a solution of carbonate of soda. The precipitate thus formed, and which is pure carbonate of lime, is afterwards well washed with distilled water, and is then filtered and dried. When mixed with powdered camphor, this forms the *camphorated chalk* of the shops. Sometimes powdered pumice-stone, sifted through muslin, is added, which makes it a more effective tooth-powder for discoloured teeth.

Chalk, carefully prepared, is much used in medicine as an antacid, in the form of chalk mixture, and chalk lozenges; it is also an ingredient in *aromatic confection*.

Salts of lime.---Muriate of lime, or chloride of calcium, which is a constituent of sea-water, may be readily prepared by dissolving chalk, or marble, in muriatic (hydrochloric) acid. Carbonic acid escapes, and the chloride remains in solution. This solution be afterwards evaporated, until concentrated, and set aside to cool, crystals of chloride of calcium will be formed. It is a very deliquescent salt, and attracts moisture from the atmosphere very quickly, so much so indeed, that after a short exposure to a moist atmosphere, the crystals become converted into a liquid mass. If the crystals of chloride of calcium be fused at a red heat, this substance becomes phosphorescent, and all the water of crystallization is expelled.

When crystals of chloride of calcium are dissolved in cold water, they produce intense cold, and from this cause the salt is sometimes employed in making freezing mixtures. If two parts of snow, or powdered ice, be mixed with three parts of crystallized chloride of calcium, the temperature of the mixture will be lowered from 32 degrees Fahrenheit to 50 degrees below zero, thus producing 82 degrees of cold. This salt has so great

an affinity for water that it is employed in the rectification of alcohol. If the dried crystals are mixed with spirit containing a small percentage of water, and the mixture well shaken, in a few moments the water will be absorbed by the salt, and will subside in the form of an oily liquid.

Sulphuret of calcium.—There are many combinations of sulphur with lime. A *protosulphuret of calcium* is formed when dried gypsum (sulphate of lime) is mixed with a small proportion of powdered charcoal, and the mixture calcined, in a covered crucible, at a powerful heat. A *bisulphuret of calcium* is produced when equal parts of powdered sulphur and slaked quicklime are mixed with water and boiled. The solution, on cooling, deposits crystals of the salt.

Acetate of lime is formed by adding carbonate of lime to acetic acid until the latter is neutralized. The liquid is then evaporated at a gentle heat, and afterwards set aside to cool, when crystals of acetate of lime will be formed.

When wood vinegar (*pyroligneous acid*) is neutralized with powdered chalk, *pyrolignite of lime* is produced, which is used by dyers and calico-printers in the preparation of "mordants."

Chromate of lime is prepared by Mr. Charles Watt's process as follows:—The green liquor resulting from the bleaching of palm oil by chromic acid, and which contains a large quantity of *oxide of chromium*, is placed in a wooden vat, and to this is added, gradually, *milk of lime* (made by mixing slaked lime with water), which first neutralizes the excess of acid present. After about an hour's repose, the clear liquor is drawn off into another vessel, and milk of lime again added, with constant stirring, until the liquor, after a few moments' rest, is clear and colourless. The precipitate thus formed is allowed to subside, when the liquid is again poured off, and the precipitate is well washed with water repeatedly. Finally, the last water is run off, and

the green deposit is placed upon a cast or wrought iron plate, fixed in brickwork, with a fireplace beneath. The mass is heated gently at first, to expel the water, and afterwards the heat is increased, until the mass, which forms into thick cakes, begins to appear *yellow* on its lower surface. The roasting is allowed to proceed gradually, and the cakes are turned over when about half roasted, and, after a while, the *chromate of lime* which is formed assumes the condition of a rather coarse yellow powder. When the roasting is complete, which is known by its uniform colour, the material is placed in casks, and is used again, with hydrochloric acid, in the process of bleaching palm oil.

Nitrate of lime is formed by dissolving lime or chalk in nitric acid.

The sour principle of the *whey* of milk is due to an acid called *lactic acid*. If this be neutralized with slaked lime, and the solution filtered and evaporated, *lactate of lime* is obtained, in a crystalline form, on cooling.

INTERESTING NOTES.

DARWIN stated that a deposit of salt and gypsum, two feet in thickness, occurred on the shores of the Isle of Ascension, which was formed by the dashing of the waves; and Dana also discovered beautiful crystals of selenite in logs of half-decomposed wood in the shore cliffs near Callao, which originated in a similar way.

If a drop of sea-water be slowly evaporated, under a microscope of high power, crystals of selenite (sulphate of lime) are produced, having the form most common in native crystals of the mineral. On adding more water, the crystals are again dissolved, and this may be repeated indefinitely. These results would seem to indicate that the lime was mostly in the state of sulphate.—*Dana*.

Sulphate of lime is soluble in about 500 parts of water, but when salt is present (as in sea-water) a much larger quantity of the sulphate will be dissolved by this fluid.

Blasting rocks with lime.—Any method of removing large masses of mineral matter from their native beds, which is less

dangerous to miners and quarrymen than gunpowder or other explosives, deserves the highest consideration, more especially as the blasting operations are too often placed in the hands of men possessing more courage (or rather ignorance of danger) than prudence. It is less than a year since that a foreman employed at a chalk quarry near London, and whom the author knew well as a steady workman, was fearfully injured while withdrawing a charge of gunpowder which, from some cause, had failed to ignite. In trying to recover the old charge, with hammer and chisel, it exploded with great violence, destroying both his hands, which were subsequently amputated. After months of suffering and careful hospital treatment, he returned to his duties a wiser, but not a better man.

Some time ago a series of experiments were made with quicklime, as a blasting agent, and with very satisfactory results. A hole being bored in the usual way, a charge of lime was driven into it, and this afterwards moistened by water; in a few moments the lime became heated and aqueous vapours generated, and the enormous pressure thus brought to bear upon the surrounding mass by the expansion of the vapour caused it to quietly give way, and become dislodged from its native bed, without involving the slightest risk to human life. This would appear to be an invaluable method of displacing large masses in coal mines and chalk pits.

Professor Owen says, "The *Calcaire grossier* (coarse limestone), which is employed at Paris as a building stone, contains Foraminifera in such abundance that we may say the capital of France is almost constructed of these minute and complex shells."

Dr. Davy describes a bronze helmet, of the antique Grecian form, taken up in 1825, from a shallow part of the sea, between the citadel of Corfu and the village of Castrades. Both the interior and the exterior of the helmet were partially incrustated with shells, and a deposit of carbonate of lime.

The beautiful fossil shells, called *Nummulites*, from their having a round flat form resembling a piece of money, vary in size from that of a crown-piece to microscopic diminutiveness. Owing to the enormous extent to which they occur in the latter portions of the Secondary and also in the Tertiary strata, they hold an important place in the history of fossil shells. They are frequently found heaped together in close contact, forming a considerable portion of the bulk of extensive mountains in the Tertiary limestones of Verona and Monte Bolea, and in the Secondary strata of the cretaceous formation in the Alps and Pyrenees. The Sphinx, and some of the pyramids of Egypt, are composed of limestone containing nummulites in great abundance. These shells are sometimes two inches in diameter, and belong to the order *Foraminifera*.

To account for the existence of testaceous animals, whose shells are composed of carbonate of lime, Sir C. Lyell observes, "If a large pond be made in almost any soil, and filled with rain water, it may usually become tenanted by testacea, for carbonate of lime is almost universally diffused in small quantities. But if no calcareous matter be supplied by waters flowing from the surrounding high grounds, or by springs, no tufa or shell marl are formed. The thin shells of one generation of Molluscs decompose, so that their elements afford nutriment to succeeding races; and it is only where a stream

enters a lake, which may introduce a fresh supply of calcareous matter, or where the lake is fed by springs, that shells accumulate and form marl."

Geologists have frequently speculated as to the probability of England and France having been at one period united. Verstegan, as far back as 1605, endeavoured to prove that such must have been the case, and adduced the following arguments to support his view :—First, the proximity and identity of the composition of the shores of Albion and Gallia, which, whether flat and sandy, or steep and chalky, correspond exactly with each other. Secondly, the occurrence of a submarine ridge, called " Our Lady's Sand," extending from shore to shore, at no very great depth, and which, from its composition, appears to be the original basis of the isthmus. Thirdly, the identity of the noxious animals in England and France, which could neither have swam across nor have been introduced by man. No one, he argues, would have imported wolves, for example, therefore " these wicked beasts did of themselves pass over." He imagines the ancient isthmus to have been about six English miles in breadth, composed entirely of chalk and flint, and in some places of no great height above the level of the sea.

That the crust of the earth has been subject to upward and downward movements, by which mountains have been raised above the waters, and large tracts of land submerged, is abundantly proved by the peculiar characteristics of the stratified and primary rocks. And that this upheaval and subsidence is still going on in various parts of the globe is proved by the observations of our greatest geologists. Lyell says, " Recent observations have disclosed to us the wonderful fact that not

only the west coast of South America, but also other large areas, some of them several thousand miles in circumference, such as Scandinavia, and certain archipelagos in the Pacific, are slowly and sensibly rising; while other regions, such as Greenland and parts of the Pacific and Indian Oceans, in which atolls, or circular coral islands abound, are as gradually sinking.

"That all the existing continents and submarine abysses may have originated in movements of this kind, continued throughout incalculable periods of time, is undeniable, for marine remains are found in rocks at almost all elevations above the sea, and the denudation which the dry land appears to have suffered favours the idea that it was raised from the deep by a succession of upward movements, prolonged throughout indefinite periods. Rain and rivers, aided sometimes by slow, and sometimes by sudden and violent movements of the earth's crust, have undoubtedly excavated some of the principal valleys; but there are also wide spaces which have been denuded in such a manner as can only be explained by reference to the action of waves and currents on land slowly emerging from the deep."

Syrup of sugar dissolves hydrate of lime (slaked lime), and crystals of the carbonate may be thus obtained, by boiling hydrate of lime 1 part, sugar 3 parts, and water 6 parts. When cold, the solution is to be filtered, and the clear liquor set aside, and exposed to the air for about two weeks, when crystals will be deposited.

Donati ascertained the existence of a compact bed of shells,

100 feet in thickness, at the bottom of the Adriatic, which, in some parts, was converted into marble.—*Dr. Mantell.*

The *fur*, or incrustation which lines the interior of kettles and boilers in which water has been boiled, is carbonate of lime deposited from water after the carbonic acid, which held it in solution, has been expelled by heat.

All waters contain more or less carbonate of lime in solution; but the springs which issue from calcareous rocks, as in Derbyshire, San Filippo, etc., contain so large a proportion that advantage is taken of this for making ornaments; baskets, leaves and twigs of trees, wooden crosses, vases, etc., and many other objects, are deposited in the water issuing from the springs, and these soon become coated with an incrustation of carbonate of lime. Indeed, moulds of various objects are also placed in the running streams, and these, becoming coated with the calcareous deposit, yield very beautiful impressions.

Many of the buildings of ancient and modern Rome are constructed of tufa, or travertine (carbonate of lime), from the quarries of Ponto Luccano, which are believed by Dr. Mantell to have originated from lakes fed by calcareous springs. Referring to these calcareous deposits, Sir Humphrey Davy says, "The waters of these lakes have their rise at the foot of the Apennines, and hold in solution carbonic acid, which has dissolved a portion of the calcareous rocks through which it has passed; the carbonic acid is dissipated by the atmosphere, and the marble, slowly precipitated, assumes a crystalline form, and produces coherent stones. The acid originates in the action of

volcanic fires on the calcareous rocks of which the Apennines are composed; and carbonic acid being thus evolved, rises to the source of the springs derived from the action of the atmosphere, gives them their impregnation, and enables them to dissolve calcareous matter."

Dr. Mantell says that the formation of travertine is so rapid, that not only the vegetables and shell-fish are surrounded and destroyed by the calcareous deposition, but that insects also are frequently incrustated with carbonate of lime. Sir H. Davy, who investigated the remarkable Lake of Solfatara, near Rome, found that its temperature, even in winter, was 80 degrees Fahrenheit; and that so rapid was the deposit of calcareous matter (travertine) from the water, that vegetables (*confervæ*, lichens, etc.) which grew with marvellous rapidity in the warm atmosphere, surcharged with carbonic acid, became incrustated with the calcareous deposit almost as soon as developed, and, breaking away from the banks, floated down the stream forming little islands. To ascertain the rate of this deposit, Sir Humphrey fixed a stick on a mass of travertine, covered by water, and in about eleven months after he examined it, when he found that a deposit of several inches in thickness had formed on the bottom of the stick. The upper part was a mixture of light tufa and leaves of *confervæ*; below this was a darker and more compact travertine, containing black and decomposed masses of *confervæ*; in the lower part the travertine was still more solid, of a grey colour, but with cavities, which he believed were produced by the decomposition of vegetable matter.

"I have passed many happy hours, I may say days," says Sir H. Davy in his charming work, "The Last Days of a

Philosopher," "in studying the phenomena of this wonderful lake; it has brought trains of thought into my mind connected with the early changes of our globe; and I have sometimes reasoned from the forms of plants and animals preserved in marble, in this thermal source, to the grander depositions in the secondary rocks, where the zoophytes or coral insects have worked upon a grand scale, and where palms and vegetables, now unknown, are preserved with the remains of crocodiles, turtles, and gigantic extinct saurian animals, which appear to have belonged to a period when the whole globe possessed a much higher temperature. I have likewise often been led, from the remarkable phenomena surrounding me in that spot, to compare the works of man with those of Nature. The baths, erected there nearly twenty centuries ago, present only heaps of ruins; and even the bricks of which they are built, though hardened by fire, are crumbled to dust; whilst the masses of travertine around, though formed by a variable source from the most perishable materials, have hardened by time, and the most perfect remains of the greatest ruins in the eternal city, such as the triumphal arches and the Colosseum, owe their duration to this source."

Amongst the innumerable evidences of the continual changes that are taking place in the earth's crust, both above and beneath the waters of the ocean, is an interesting fact, noticed by Dr. Paris:—"A sandstone occurs in various parts of the northern coast of Cornwall, which affords a most striking example of a recent formation; since we here actually detect Nature at work in converting calcareous sand into stone. A very considerable portion of the northern coast of Cornwall is covered with a calcareous sand, consisting of minute particles of comminuted

shells, which, in some places, has accumulated in quantities so great as to have formed hills of from forty to sixty feet in elevation. In digging into these hills, or upon the occasional removal of some part of them by the winds, the remains of houses may be seen; and in some places, when the churchyards have been overwhelmed, a great number of human bones may be found. The sand is supposed to have been originally brought from the sea by hurricanes, probably at a remote period."

- Dr. Mantell was of opinion that the disintegration of granite rocks is caused by the action of carbonic acid upon the felspar, which, with quartz and mica, constitutes granite. Since, however, common felspar always contains a considerable quantity of potash, is it not more probable that this disintegration, which is so remarkably manifest on the shores of Dublin, near Killiney, and along the coast of Wicklow, is due to the action of water? Here the disintegrated granite occurs in large coarse particles upon the beach, into which the feet sink so deeply as to produce a feeling of insecurity, and even danger. The percentage of potash in the granite rocks of this district is so considerable (even as high as 17 per cent., according to some authorities) that the author and his brothers, while on a visit to Dublin during the rebellion of 1848, made a series of experiments with a view to extract the potash, as a commercial enterprise, but the disturbed state of the country at that time put an end to the attempt.

On the shores of the Bermudas a most interesting deposition of limestone is taking place, which is principally composed of calcareous materials thrown up by the sea. The ocean which surrounds the Bermudas abounds in corals and shells, and from

the action of the waves on the coral reefs and on the dead shells, the waters become loaded with calcareous matter. Much of this detritus, no doubt, is carried down to the profound depths of the ocean, and there envelops the remains of animals and vegetables, thus forming new strata for the use of future ages; but a great proportion is wafted by the waves towards the shores, and is deposited in the state of fine sand. This sand is drifted inland by the winds, and becomes more or less consolidated by the percolation of water and the infiltration of crystallized carbonate of lime; and a white calcareous stone is thus formed, which in some localities is sufficiently compact for building.—*Mantell*.

It has been estimated that five hundred millions of animalculæ may be contained in a single drop of water, and that upwards of two thousand millions of *Miliola* are contained in a cubic inch of Paris limestone. We are now told that the decaying bricks of all our buildings in London and elsewhere are densely inhabited by special animalculæ. M. Parize has stated that he has seen with the microscope, in every portion of crumbling, weather-worn brickwork, minute living organisms, which are believed to be the real destroyers of the surface, and even walls of buildings. This announcement, although somewhat surprising, is far from being ridiculous, for we know that all porous materials—and some varieties of bricks and stone are exceedingly porous—absorb water, and that the air and water abound in germs and infusoria; it is therefore but reasonable to believe in the possibility, nay, probability of the fact discovered by M. Parize.

Referring to the food of *Infusoria*, Dr. Mantell observes—
“However improbable it may appear to the mind unaccustomed

to investigate the works of the Creator, that beings so minute as those under examination should prey upon living forms of yet more infinitesimal proportions, the fact is nevertheless unquestionable. It is even possible to select the food of animalcules much smaller than the polypi of the flustra,* and thus exhibit their internal structure! The animals called *monads* may be considered as the lowest limit of animated nature, so far as cognizable by man, their diameters varying from the twelve hundredth part of an inch to the *twenty-four thousandth*, and the powers of the microscope will extend no farther."

Flints, which abound in the upper chalk, are composed almost entirely of silica, with, sometimes, traces of iron. When broken, they invariably exhibit some evidence of a *nucleus*, either in the form of a sponge, shell, sea-urchin (*Echinus*), or other marine organism, round which the silicious matter had deposited, probably from waters holding silica in solution. The *silicification*, or petrification of animal and vegetable substances by silica, is remarkably illustrated in specimens of petrified wood, and the numerous echinites which, although they possess the hardness of the flint, yet preserve their original structure. It is a remarkable fact, however, that the organic matter of the animal or vegetable substance is in some instances totally absent from the petrified object, the form alone indicating its origin.

According to M. Lewy, who made some very important investigations concerning the formation and composition of emeralds brought by him from New Granada, the emerald is always accompanied by calcareous spath, quartz, and pyrites;

* A genus of polyparia.

but as the quartz envelops it, and as it in its turn envelops the pyrites, this double relation defines a determinate order of successive crystallization. The emerald impacts also more or less calcareous matter constituting its gangue (the mineral matters surrounding it); we often see thin sheets of this calcareous matter dividing the purest crystals into two or three parts, but it accumulates especially towards their base. The crystals then become nebulous (cloudy), and sometimes so incoherent, that on being taken from the mine, they are almost friable between the fingers.

Speaking of coral islands and their submarine origin, Sir H. De la Beche says—"There can be little doubt of coral banks and reefs similar to those in the seas of our time, and in coral-reef regions, having been raised above the surface of the sea, like other marine accumulations, forming dry land. Such have long been known. MM. Quoy and Gaimard, who accompanied the expedition of M. Freycinet, and who remarked on the moderate depths to which the reef-making corals appear to extend, mention that on the coasts of Timor, coral banks so occur above the sea level as to have induced M. Peron to consider the whole land formed of them."

Mr. Thornton Herapath found that all soils contain an appreciable quantity of nitric acid, in the form of nitrates of lime, ammonia, soda, and potash, and he believed that this acid, whether free or combined, acted both as a stimulant and as a true manure. Moreover, he was of opinion that most plants have the power of decomposing the earthy and alkaline nitrates, and that some "actually appear to possess the power of transforming ammonia or nitrogenous compounds into nitric acid."

In examining a specimen of fossil ivory, M. Wicke found that the internal portion contained about 67·94 per cent. of phosphate of lime, and 18·45 per cent. of carbonate of lime. The enamel gave 47·51 phosphate of lime, and 10·83 carbonate of lime. The organic matter in the internal part was 6·38 per cent., while in the enamel it amounted to 28·57 per cent.

Concluding Observations.—The sublime effect of geological research upon the minds of those great observers who have unfolded so many of the hidden mysteries of our globe, is shown in their universal recognition and appreciation of the Great First Cause of All. It is impossible to peruse the works of our gifted geologists without seeing how deeply they were impressed with an unfeigned belief in that Almighty Being, without whom “was not anything made that was made.” In the present age of affected scepticism—resulting from ignorance of Nature and inordinate love of Art—it is mentally refreshing to read the works of those great lovers of Nature, who have done so much to enlighten us upon the history of our planet and to instruct us in the wonders of Creation.

“For my own part,” said Dr. Mantell, “feeling as I do, the most profound reverence and the deepest gratitude to the Eternal, who has given me this reasoning intellect, however feeble it may be; and believing that the gratification and delight experienced in the contemplation of the wonders of creation here, are but a foretaste of the inexpressible felicity which, in a higher state of existence, may be our portion hereafter; I cannot but think that the minutest living atom, which the unaided eye of man is able to explore, is designed for its own peculiar sphere

f enjoyment, and is alike the object of His mercy and His care s the most stupendous and exalted of His creatures."

There can be no doubt whatever that the study of natural history exalts and purifies the mind, filling it with pleasing and wonderful facts—a healthy store, the accumulation of which is not only a labour of love, but is a source of inestimable enjoyment. Truly,

"The appetite grows with what it feeds on"

when once the human intellect is devoted to the contemplation of the transcendent wonders of our varied and beautiful sphere.

Well would it be for the future of mankind if our Board Schools and other educational establishments were to instil into the minds of the young, some knowledge of the globe on which they live, and of the marvellous beauties which adorn it.

In the foregoing pages an attempt has been made to bring together a series of facts more or less connected with the subject selected—a Lump of Chalk—and to show how widely-diffused throughout the globe is the substance known as lime. However imperfect such a small treatise upon so vast a theme must necessarily be, the author indulges a hope that the information given may induce many of his readers to seek further knowledge at the hands of those eminent authors, to whose valuable works he was so greatly indebted in compiling this little volume.

Amongst the numerous works consulted in the preparation of these pages, may be mentioned the following :—

"The Wonders of Geology," by Dr. Mantell. "Palæontology," by Professor Owen. "The Geological Observer," by Sir H. De la Beche. "Mineralogy," by Dr. Percy. "Museum of Science and Art," by Dr. Lardner. "Principles of Geology," by Sir C. Lyell. "Geology of Yorkshire," by Professor Phillips. "Geology," by Dr. Buckland.

GLOSSARY.

Alga, sea-weeds.

Arenaceous, sandy.

Argillaceous, of the nature of clay.

Astrea, star coral.

Atolls, coral islands of an annular or ring-like form.

Augite, the principal mineral in many trap and volcanic rocks.

Basalt, ancient lava, composed of augite and felspar.

Belemnite, the bone of an animal of the cuttle-fish kind.

Bivalve, having two shells, like the oyster.

Botryoidal, like a cluster of grapes.

Breccia, applied to a species of marble which occurs in irregular angular fragments.

Calcareous, having the properties of lime.

Calcium, the metallic base of lime.

Calc sinter, deposition from hot springs charged with carbonate of lime.

Calx, lime.

Carboniferous, belonging to coal.

Cephalopods, mollusca, having the organs of motion round their
as the cuttle-fish, nautilus, etc.

Chalcedony, a species of siliceous or silica.

Chert, a silicious mineral allied to flint and chalcedony.

Chaonite, a zoophite of the chalk.

Chondrites, marine plants of the chalk.

Comminuted, pulverized.

Conchoidal, shelly.

Confervites, fossil aquatic plants of the chalk deposit.

Corn brash, a coarse shelly limestone.

Cretaceous, belonging to chalk.

Crinoides, lily-shaped animals.

Delta, alluvial deposits formed by rivers.

Detritus, matter which has been worn or rubbed off rocks.

Echinus, sea-urchin.

Encrinite, a genus of crinoidea.

Eocene, the beginning of the present epoch.

Escarpment, the abrupt face of a ridge of high land.

Exuviae, a term applied to all kinds of fossil animal remains.

Fauna, the entire group of animals belonging to a country or period.

Felspar, a mineral which, with quartz and mica, constitutes the chief material of rocks. Potash or soda, and sometimes both alkalies, are found in this mineral.

Flustra, a genus of polyparia.

Foraminifera, a class of minute chambered cells.

Gault, or *galt*, a name applied to a series of beds of clay and marl. Its geographical position is between the Upper and Lower Green-land

Greensand, a stratum of the chalk deposit.

Gypsum, native sulphate of lime.

Hornblende is a term applied to a series of minerals composed of silicates of metallic oxides, as lime, magnesia, manganese, etc., and in which fluoride of calcium is generally present.

Infusoria, microscopic animals, so-named from being found in putrid vegetable infusions.

Lacustrine, belonging to a lake.

Lias, is a name given to an argillaceous limestone containing peculiar fossils, and occurs below the oolite series of strata.

Littoral, belonging to the shore.

Madrepore, a genus of corals.

Marl, a mixture of clay and lime.

Marsupial, a term applied to animals having a pouch, like the kangaroo, etc.

Marsupite, a genus of crinoidea of the chalk.

Mandrina, a genus of corals with meandering cells, as the brain coral.

Mollusca, soft-bodied animals, having no bony structure, as the oyster etc.

Nodular, rounded, but of irregular form, as a flint.

Oolite, a limestone, so called from its being composed of rounded particles resembling the roe or eggs of fish.

Organic remains, the relics of animals and plants.

Outcrop, extreme edge of inclined strata.

Outlier, detached portion of a formation.

Palaeontology, the science which treats of the structure of ancient extinct animals.

Polyptaria, corals belonging to the great division in the animal kingdom called Radiata.

Polypti, marine animals which form corals.

Quartz, pure silica.

Septaria, nodular masses of clay, having crevices filled with spar

Silex, flint.

Silicified, changed to flint.

Silicious, flinty.

Spatangus, a genus of sea-urchin.

Stalactites, pendant conical masses of carbonate of lime, found in caverns.

Stalagmites, concretions of carbonate of lime formed on the floors of caverns by the dripping from stalactites.

Stinkstone, bituminous limestone.

Tertiary, a term applied to the strata which occur above the chalk

Testacea, shell-fish.

Testaceous, having a hard shell.

Thermal, hot springs, those waters which have a higher temperature than 60° Fahr.

Trap rocks, ancient volcanic rocks, derived from a Swedish word, *trappa*, a stair.

Tubifera, coral resembling organ pipes.

Tufa or *Travertine*, a deposit of carbonate of lime from water.

Univalve, having one shell, as the periwinkle.

Zamites, fossil plants of the oolite, etc.

Zoophytes, animal plants, applied to corals, etc.

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Blackburn Standard.

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Hastings and St. Leonards Times.

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Sheffield Independent.

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Liverpool Courier.

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Jersey Express.

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